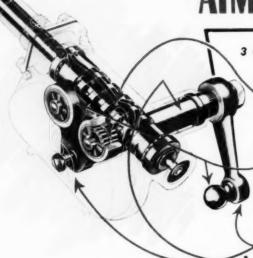


# There's Long, Hard Wear in STEERING GEARS

# ...put THERE BY SURFACE PREPARED ATMOSPHERES



Ever hear of an auto accident due to steering gear going bad? Quite likely you never will, because right before your eyes is proof that steering mechanisms (other parts and products, too) are made safe and dependable.

All vital and moving parts of the steering assembly shown above undergo one or more controlled atmosphere heat treatments: carburizing, cyaniding, clean hardening, where results are uniform and consistently within close tolerances.

These controlled atmosphere heat treatments are carried out in radiant tube-fired furnaces of types best suited for handling the particular parts. The furnace types include pit, rotary hearth and continuous articulated link belt types.

# RX PREPARED ATMOSPHERES

Atmospheres for these 3 distinctly different heat treat processes are prepared in 2 centrally located 'Surface' RX generators manifolding the RX carrier gas for all atmosphere requirements. Saves money, saves space!

# 3 Controlled Atmospheres for Heat Treating

Work flow in the plant producing this steering gear is arranged around 3 controlled atmosphere processes: carburizing, dry cyaniding, clean hardening.

"heart" of the assembly, are carburized in 4 'Surface' pit type radiant tube furnaces each with an enriched RX controlled atmosphere. Each furnace handles about 1500 lbs. net. Minimum hardenable case depth of 0.040-in.

Dry Cyaniding: Studs and balls subject to frictional wear and impact stress in final assembly are given optimum physical properties by a dry cyaniding treatment with a 'Surface' RX atmosphere enriched with natural gas and ammonia. Studs are cyanided to case depth of 0.008-in. Balls are treated to case depth of 0.010-0.015-in. Heat treatments are accomplished in a continuous articulated link belt furnace.

\*\*Clean Hardening: Lever shafts and steering arms are first isothermally annealed, then clean hardened in a 'Surface' rotary hearth furnace with radiant tubes and an RX controlled protective atmosphere.

'Surface' RX generators for making prepared atmospheres are employed successfully in hundreds of plants for many processes: carburizing, clean hardening, bright annealing, carbon restoration, homogeneous carburizing and dry cyaniding.

'Surface' is a pioneer in prepared atmosphere equipment, furnishing not only RX, but also DX, NX, HX, HNX, AX and Char-Mo gas atmospheres. Send for Bulletin SC-155 on prepared atmospheres. Write today on your letterhead.



SURFACE COMBUSTION CORPORATION . TOLEDO I, ONIO

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# RETURN YOUR SCRAP

to make mill products

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# As I was saying



NEVER grow weary of telling this story, which is ever new to a large number of new members of .:

The A.S.M. was organized in 1913 in Detroit by Billy Woodside . . . had then 12 members, now 21,000; 60% are engaged in the fabrication of metals, 25% in production of ferrous and nonferrous metals, 15% in education and research . . . is the only engineering society dealing with all phases of the metals industry . . . is the largest group of metal engineers in the world . . . has 80 chapters holding 500 meetings a year with 50,000 attendance . . . sponsors chapter educational courses attended by over 16,000 annually . . . publishes the Metals Handbook, bible of the metals industry . . . publishes Metal Progress, the engineering magazine of the metals industry . . . publishes Transactions, the technical volume of annual convention papers supplies over 45,000 preprints of convention papers . publishes Metals Review containing the only prompt and complete review of metal literature.

In one year the collected, edited, printed and distributed over 100 million pages of engineering information on the subject of metals.

conducts the most intense promotion in the world for ferrous and nonferrous metals . . produces and distributes moving pictures on metallurgical subjects . . provides a no-cost employment service . . . has distributed over 100,000 booklets and leaffets describing a career as a metals engineer . . is the largest publisher of engineering books for the metals industry in the world . . . owns and operates the National Metal Exposition and the Western Metal Exposition . . holds an annual metallographic exhibit . . is the instigator and general manager of the National Metal Congress . . . is sole sponsor of the World Metallurgical Congress . .

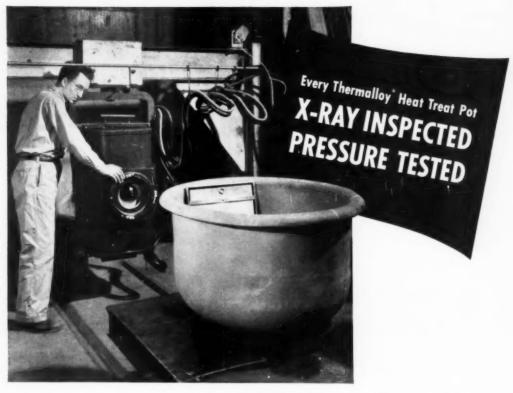
Through the Metallurgical Advisory Board, appoints committees to serve as advisory to the United States Navy . . . also serves by appointment as the agency for the distribution of metallurgical information to the profession.

has not increased its dues (\$10) since the Society was organized . . returns an average of 40% (\$85,000 each year) to the chapters . . expends annually on each member \$44.50 . . has an annual budget of over one million dollars . . has established the annual teaching awards in metallurgy . . is fathering the establishment of a new highly technical and theoretical international publication for the metals industry . . and many other important projects now in the making and soon to be announced.

From where I sit it seems to me that all the members of the should be mighty proud of their fine accomplishments enumerated above, because they never would have been possible without the 100% cooperation of 100% of the members.

Cordially yours,

W. H. EISENMAN, Secretary AMERICAN SOCIETY FOR METALS



# HERE'S PROOF OF QUALITY!

- Life of Electro-Alloys neutral salt pot proved to be eight times that of competitive type pot formerly used. User saved over \$100 on initial cost alone during life of one pot—plus replacement labor costs of seven pot changes.
- With a competitive alloy, customer was receiving 1,500 to 3,500 hours service. On switching to Thermalloy pots, service life jumped to 3,800-5,550 hours in identical service.

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To insure the soundness necessary for low-cost service, every Thermalloy Heat Treat Pot is subjected to thorough internal and external inspection. Two X-ray machines, operated by trained radiographers, reveal any hidden flaws or weaknesses which might shorten service life. Pots are also pressure-tested at 60 pounds per square inch. This eliminates the possibility of porosity that does not show up on X-rays.

This careful inspection, plus Thermalloy's outstanding heat-resistant properties, are your guarantee of top quality. Why not make Thermalloy your standard in

buying heat treat pots?



Over 100 sizes in both round and rectangular pots are available for production from stock patterns. Write for Bulletin T-205, listing shapes and sizes available. Electro-Alloys Division, 2094 Taylor St., Elyria, Ohio.

Specify THERMALLOY® for heat and abrasion resistance...CHEMALLOY® for corresion resistance

\*Reg. U. S. Pat. Off.

Brake Shoe

ELECTRO-ALLOYS DIVISION

APRIL 1952; PAGE 1

MAXIMUM SHOCK RESISTANCE MOST ECONOMICAL

HOLD CLOSE TOLERANCES LONGER

LONGER RUNS

MEET N.P.A. REQUIREMENTS

WITHOUT RESHARPENING

SETTER RESISTATION TO WEAR AT HIGH TEMPERATURE LARGE QUANTITY PRODUCTION PER TOOL

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Firth Sterling MOLY HIGH SPEED STEEL

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BETTER ... FASTER ... CHEAPER

There is a Firth Sterling high speed steel for every purpose . . . whether high speed cutting, holding close tolerances, machining abrasive material, general shop work, or specialized application. The right steel will increase production, reduce down-time and save

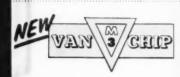
many times the actual cost of the steel.

Choose the RIGHT STEEL SEND FOR THESE HELPFUL BULLETINS

(देशक्षात्रक्ष)

An 8% cobalt moly steel possessing great cutting capacity, unusual RED-HARDNESS value, and toughness.

For complete information on Circle M, ask for Bulletin SL-2032



Its higher vanadium and carbon content combine to produce superior WEAR-RESISTANCE . ideal for cutting hard materials . . . and for holding close tolerances.

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A moly-tungsten steel recommended for GENERAL MA-CHINING operations.

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A made-to-order steel for SPE-CIAL PURPOSE applications.

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9.254

# Dependable temperature control to 1000 F

Connection between the instrument and its primary element (a Thermohm temperature detector) is wire ... not tubing. Can be any length without affecting accuracy or dependability.



Typical samples of the information available on Flortenmax Central. Specify nature of process and whether fuel is gas, ail, steam or electricity.

ELECTROMAX Controllers give modern electronic regulation to thousands of important manufacturing processes. In any application up to 1000 F they exactly fill the bill for non-recording controllers of outstanding dependability.

Electromax has the sensitivity, accuracy and dependability of its big brother Speedomax Recording Controller. Likewise, it is not affected by vibration or building tremors . . . can even be mounted on the frame of a molding press. The instrument needs almost no attention, because it has only one moving part . . . a covered plug-in type relay. There's usually no need to open the instrument door for months at a time.

Electromax Control is available to provide any one of three control actions. For the more simple process requirements, on-off or two position control is usually used. For processes requiring control within unusually close limits, two different types of proportional control are available . . . Position-Adjusting Type and Duration-Adjusting Type. All three types of control action can be applied to electric, steam or fuel heating.

For further information, write our nearest office, or 4927 Stenton Ave., Phila. 44, Penna.

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LEEDS & NORTHRUP CO.

APRIL 1952; PAGE 3

Metal Progress is published and copyrighted, 1952, by for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions \$7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

# HOW THE SCRAP THAT JACK MADE — MADE JACK AND MORE



This is the Scrap that Jack made.



This is the Man who found the Scrap that Jack made.



This is the Clerk who was called by the Man who found the Scrap that Jack made.



This is the Dealer who dealt with the Clerk who was called by the Man who found the Scrap that Jack made.





This is the jack the dealer paid for the Scrap that Jack made.

# AND THIS IS THE STEEL THAT INDUSTRY GETS



from the Scrap that Jack made!

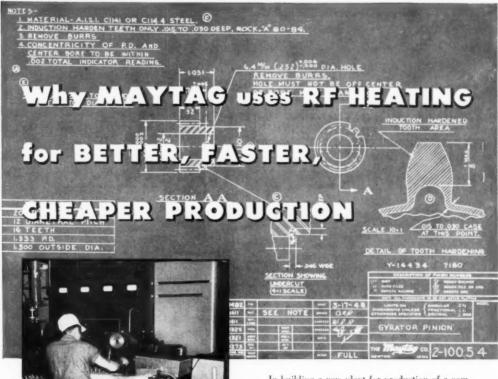
# MORAL:

Check your Plant for Scrap Today and Get it Moving — That Pays Everybody!

Superior Steel

CARNEGIE, PENNSYLVANI





The Maytag Company has found, for fast production at low cost and high quality, Westinghouse RF Heating installations are the answer.

The installation of a process using two 20 KW-450 generators—for both spline and straight shaft hardening—has paid for itself in less than 3 months! This was shortly after World War II, and since then continued use has piled up real profit in savings.

In building a new plant for production of a completely new line of automatic washing machines, Maytag turned to induction heating for brazing and hardening... and they specified Westinghouse. A 50 KW and 10 KW RF generator, with associated work handling equipment, are now accounting for still further savings and continued high quality. That's why Maytag says that not only is the Westinghouse RF process the best method for heat treating production parts, but, also, "it produces precision work at the price of rough and ready work."

As we helped Maytag, let us help you solve your problems of increased production at low cost and with high quality. By all means, investigate the possibilities of installing Westinghouse RF Heating.

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Westinghouse Electric Corporation Department P-41 2519 Wilkens Avenue 'Baltimore 3, Maryland

. . . . . . . . . . . . . . . . . . . .

Send me your informative case history booklet on induction heating.

Name

Company

Street







The name, UTICA, famous for quality forged tools for more than 50 years, now identifies a foremost supplier of turbine and compressor blades to the aircraft engine industry,

# BY MAKING TODAY'S METHODS "OLD FASHIONED"

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So, whether you come into contact with UTICA tomorrow or several years from now, you'll find leadership that reflects this constant hunger for progress. UTICA seeks to help most by working most for advancement.



UTICA DROP FORGE & TOOL CORPORATION, Utica 4, New York

NEUTRAL HARDENING

# Chacks

YOUR HEAT TREATING PROBLEM
FOR NATIONAL DEFENSE

# ..AJAX Has the Answers!

4 out of 5 metal products for defense use can be heat treated better, faster, with less floor space and at lower cost with an Ajax Salt Bath Furnace than by any other method! This statement is proved by the widespread use of Ajax furnaces during World War II and by the even more marked trend toward this exclusive salt bath method in today's rearmament program. And we'll be glad to prove it specifically by heat treating specimen batches of your materials under actual shop conditions in the Ajax Metallurgical Service Laboratory. There is no obligation on your part. You be the judge!

SOLUTION HEAT TREATMENT OF ALUMINUM

ANNEALING

DRAWING

AUSTEMPERING

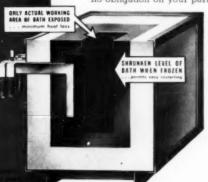
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HEATING FOR FORGING

DESCALING



Ajax Submerged Electrode Furnaces\*, equipped with refractory pots, reduce maintenance costs to the vanishing point because pot and electrode life is measured in years.

Patented in U.S. and foreign countries.

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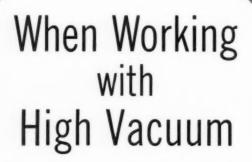
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Select the equipment to fit the job from the complete line of National Research

Vacuum Equipment







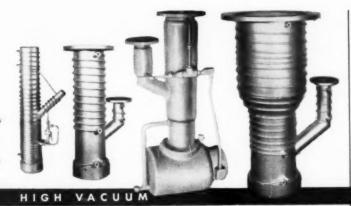


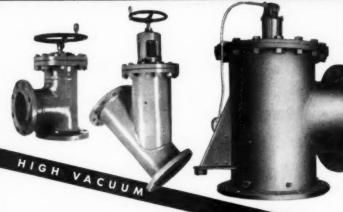
















# Special Equipment and Plant Installations



V25D Retary Condenser. A typical processing unit in a large, high vacuum plant which we designed and built.



Vacuum Fusion Gas Analyzer. Analyzes metals and allays, including titanium, for combined or dissolved oxygen, nitragen, and hydrogen.

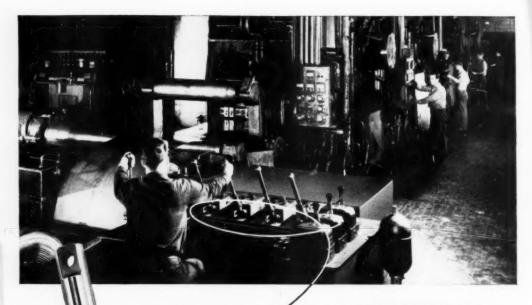
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Gain the benefits of the high standards of practical performance built into all National Research products. Write us for further details.

National Research Corporation

**Equipment Division** 

SEVENTY MEMORIAL DRIVE, CAMBRIDGE, MASSACHUSETTS



# Free-Machining ENDURO **Helps Control Stainless Machining Costs**

In pneumatic and hydraulic control valves, ENDURO Stainless Steel plungers help boss big mills like this . . .

The ENDURO plungers-through which air, water, and oil flow under thousands of pounds pressure — must resist corrosion, resist abrasion, and maintain a tight seal at all times. They must be fully balanced so that they cannot creep or crawl.

All this requires a lot of machining . . . upwards of 30 separate operations. Free-Machining ENDURO Bars are cold finished by Republic's Union Drawn Division especially for efficient, economical production of all such highlymachined parts. They provide close tolerances, accuracy of section, uniform soundness, and fine surface finish, together with the high physical and chemical properties of stainless steel. Two grades are 90% as machinable as Bessemer screw stock.

Free-Machining ENDURO also is available in hot rolled bars, and in wire. Republic metallurgists are ready to give prompt assistance on applications, processing and use. Write:

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Alloy Steel Division . Massillon, Ohio GENERAL OFFICES CLEVELAND 1, OHIO

Export Department: Chrysler Building, New York 17, N. Y.

Republic ENDURO

REALTH STATES STEET

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Other Republic Products include Carbon and Alloy Steels-Pipe, Sheets, Strip, Plates, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

METAL PROGRESS: PAGE 10

# ROLLICK ALLOYS



"Serpentine" grid (pat. applied for), removable work dividers. Wt. 70 lbs., load 330 lbs...ratio about 5 to 1.

# MINIMIZE REJECTS CUT COSTS

IN ORDNANCE
HEAT TREATING
...PICKLING

New Catalog shows many exclusive designs produced for leading metal working plants. Copy on request.



Pit type furnace basket for heat treating shell cases. Two layers of shells, mesh separator. Basket has loose shell, easily replaced. Fabricoted grid, long life.



Monel pickling rack designed for 2000 lb. load in 8% H<sub>2</sub> SO<sub>4</sub> at 165° F. Wt. 500 lbs., ratio 4 to 1.



Lock-crimp, woven wire shell case basket, flat bottom, travels an rolls, either direction. Anneal and pickle. Wt. 54 lbs., load 330 lbs., rotio 6½ to 1.

Monel pickling barrel for cupped steel parts. Load 3500 lbs. Low H.P. standard speed motor drive thru bronze sprocket and chain.

sprocket and chain.

Offices: PHILADELPHIA. CLEVELAND, DETROIT, HOUSTON, INDIANAPOLIS, CHICAGO, ST. LOUIS, LOS ANGELES, MINNEAPOLIS, PHYSBURCH ROLOCK INC. • 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

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Today American industry is constantly searching for ways to lighten the unprecedented load on its production facilities. Progressive manufacturers have discovered that magnesium . . . with its combination of lightness, strength and workability . . . is one answer. These characteristics of magnesium can result in simplified design, speedier fabrication and lowered production costs.

Manufacturers find that magnesium is produced in all common forms including castings, forgings, extrusions and sheet. They learn that it can be machined at the highest possible speeds of standard machine tools . . . can be formed by drawing, spinning, bending, stretching and other common production methods. Also that the metal is joined by arc, gas, and spot welding as well as by riveting and is finished by accepted methods.

So if you are making, or contemplate making, anything in which lightness or ease of fabrication is important, plan with magnesium. It has made many products better-more versatile, easier to handle, more profitable to sell-it may improve yours.



# For Your "Tomorrow's" Product . . .

Today, magnesium is a tremendously important part of our defense effort, and like many other metals, is required in great quantities by the government. But in planning "Tomorrow's" production, remember this fact: the seas, at our own shores can provide 100 million tons of magnesium per year for 1,000,000 years without significantly reducing the supply!

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# **ALLOY STEEL UNNECESSARY!**



THREE OPERATIONS ELIMINATED

. QUENCHING

• TEMPERING

STRAIGHTENING



for testing purposes.

Ground and Polished STRESSPROOF has been used for lead and feed screws by Kearney & Trecker since 1939. If STRESSPROOF were not available, they would need a .50% carbon-alloy steel to obtain the required strength and wear-resistant properties. The substitution of alloy would require quenching, tempering, and straightening—operations not necessary with Ground and Polished STRESS-PROOF. The cost of the part would be more than doubled.

For precision work, lead and feed screws for machine tools must maintain their accuracy through years of operation. Ground and polished STRESSPROOF cuts cost for these exacting parts because it provides fire qualities in the bar—(1) high strength, double that of ordinary cold-finished shafting; (2) machinability, fully 50% better than heat-treated alloys of the same hardness; (3) high resistance to near, replacing many heat-treated or carburized alloys; (4) minimum warpage, obtained by special processing; and (5) accurate, finely ground surface.

It is significant that the only suitable substitute for STRESS-PROOF is an alloy steel requiring many additional expensive production operations.

La Salle STEEL CO.

1424 150th Street, Hammond, Indiana Manufacturers of the Most Complete Line of Cold-Finished and Ground and Polished Bars in America

# TASIL

# Here's how to HOLD THAT LINING in your holding furnace

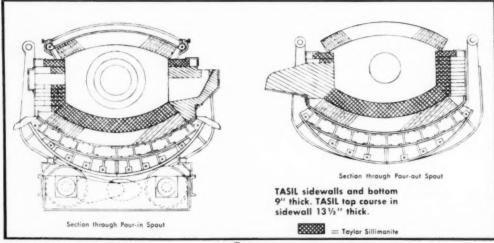
Operators of Whiting\* Cradle and similar types of holding furnaces use Taylor Sillimanite (TASIL) brick and cement to prolong the life of refractory linings. Recommended practice is to "balance" the super-duty fire brick lining with 9" of TASIL brick, laid in TASIL No. 301 Cement, for both side walls and bottom, in the areas subject to the damaging wash of molten iron and slag. (See refractory construction shown in engineering drawings below.)

A TASIL "balanced" lining at one plant is averaging 6-8 weeks on side walls and 9-12 months on

bottoms, with patching. TASIL was tried after a super-duty fire brick lining failed in three days because of joint attack and severe erosion at the metal line. This furnace is fired with pulverized coal and runs 700 tons per week of grey iron, tapped from cupola at 2750° to 2800° F.

Wherever you use fireclay-base, high alumina, kaolin or similar refractories, TASIL will give more effective service. Let a Taylor field engineer discuss with you the savings Taylor Sillimanite can make in your plant.

# Tasil "Balanced" Lining In Whiting Cradle Furnace



Built by Whiting Corporation, Harvey, III.

Exclusive Agents in Canada: REFRACTORIES ENGINEERING AND SUPPLIES, LTD. Hamilton and Montreal





Crank Cases, Frames, and other Parts for Manufacturers of Marine Steam Engines of Uniflow or Multiple Expansion Type.



Heavy Press and Machine Frames and Bases for the Machine Tool Industry.



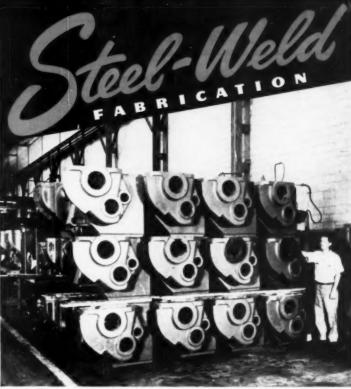
Diesel Engine Crank Cases and Frames for the Marine and Electro-Motive Field.



Pressure Vessels for the Chemical and Allied Industries.



One of Several Ports of a Catalytic Cracking Plant Produced for the Petroleum Industry.



Use WELDED STEEL for Greater Strength with Less Weight!



Mass production of these massive clutch and drive housings for a twenty-one ton tractor is further evidence of the design trend in modern machines . . . it is a typical example of how alert manufacturers are today employing Steel-Weld Fabrication to good advantage in the construction of their products. Thousands of such heavy machinery parts and assemblies are now produced and machined by Mahon for many manufacturers throughout the country. If savings in either cost or time can be effected in your product through Steel-Weld Fabrication of parts, or, if you are cramped for manufacturing space, it will pay you to investigate Mahon facilities. You will find in the Mahon organization an unique source with complete, modern fabricating, machining and handling facilities for any type of work regardless of size or weight . . . a source where skillful designing and advanced fabricating technique are supplemented by craftsmanship which assures you a smoother, finer appearing job embodying every advantage of Steel-Weld Fabrication.

THE R. C. MAHON COMPANY DETROIT 34, MICHIGAN

Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON

# **Engineering Digest**

OF NEW PRODUCTS

WELDER: A redesign of its atomichydrogen transformer welder, incorporating a new hot-start circuit, silicone insulation and a wider current range, has been announced by the General Electric Co. The current range of 10 to 100 amp, allows the use of one



machine on all applications. The range is divided into two sections, each extending the entire length of the indicator scale. The welder operates on 60 cycles, single-phase voltage; it is 41½ in. high and weighs 350 lb.

For further information circle No. 674 on literature request card on p. 32B

CUTTING FLUIDS: Magnus Chemical Co. has announced the addition of specialty cutting fluids to their line of industrial cleaning materials and machines. These fluids are designed for difficult machining operations, such as work on stainless steel, high-carbon steels and other metals where generalpurpose cutting fluids cause excessive tool wear and poor surface finishes. The Magnus products contain a much higher sulphur base content; when used for such jobs they have displayed a cost advantage over general-purpose fluids and those to which white lead or carbon tetrachloride have been added. Magnus cutting compound No. 7, undiluted, is recommended for unusually difficult machining operations. For moderately difficult jobs, 1 part No. 7 may be added to 2-5 parts of general-purpose fluids. Where staining of copper is to be avoided, Magnus cutting compound No. 6 is recommended. For difficult machining jobs where greater cooling qualities are required, Magnus soluble oils DO-4A and DO-1A are recommended. These, with their high concentration of sulphur base, are also formulated to give good rust protection and minimize the occurrence of rancidity and dermatitis. Either product is diluted 1-5 to 1-20 for machining operations, depending on the severity of the jobs, and 1-35 to 1-45 for grinding.

For further information circle No. 675 on literature request card on p. 32B

CARBURIZING BOX: The Stanwood Corp. has incorporated V-type skids for a carburizing box, giving better support for heavy loads under high-temperature use. The new construction has also resulted in improved air circulation under the bottom of the box. One-piece combination cast bottoms and legs are available for extra-heavy loading.

For further information circle No. 676 on literature request card on p. 32B

TRANSFER MACHINE: Motch & Merryweather's newest automatic transfer machine is of the progressive in-line type. It machines, cuts off to accurate length and finally chamfers both ends of the cut-off pieces. In the machine illustrated, solid cold drawn stock is fed hydraulically to the first station, which drills from



both sides. The second operation is a countersink of the drilled hole. The third and fourth stations broach flats on both sides of the stock. The fifth station cuts off where a circular saw head rapid traverse approaches, cuts to accurate length a section of the machined stock held by transfer unit, and rapid traverse returns. The hydraulic transfer unit, holding the machined and cut-off piece, returns to position on the side where two drilling units feed to adjustable stops, chamfer both ends of the piece simultaneously, and rapid traverse returns. For further information circle No. 677 on literature request card on p. 32B

EXTENSOMETER: A complete line of newly designed high-magnification S-type extensometers is now available from Tinius Olsen Testing Machine Co. These light weight instruments, which detect strain under both elastic and plastic tension test, transmit signals which rotate the recorder drum in direct proportion to strain on the specimen. Snapped on or off the specimen by merely squeezing the clamp plates, each instrument



is provided with three high magnifications. As the specimen stretches, an activating knife edge moves, which in turn moves the core of a differential transformer. This movement creates an a-c. voltage which is amplified to operate a two-phase recorder motor which drives the recorder drum on which the strain is recorded. Standard S-type extensometers are available for gage lengths of 1, 1.4, 2 and 8 in. with magnifications up to and including 1000.

For further information circle No. 678 on literature request card on p. 32B

FINISHES FOR ALUMINUM: New hard coatings for aluminum where high resistance to abrasion is desired are being released to licensees by Aluminum Co. of America. These coatings have special value where hard, long-wearing surfaces coupled with light weight are essential, as in surfaces subjected to abrasion or erosion. The new wear-resistant finishes are anodic oxide coatings. Some are made by the well-known Alumilite

s size

A sheet of exactly .020" strip steel the size of this page (81/4" x 111/4") weighs approximately 8% ounces.

The same size sheet of .022" (.020", .002" oversize) with the ellipse punched out would weigh the

Sorthen type of a frequency The converter wer other meltvarious types of as for heat treat-

tion circle No. 680 st card on p. 32B

> NG MACHINE: e the efficient the Prutton unique engispeed thread of metals hardened nchine

pen operates on the instrument reduce paper fiber cho cleaning is made easy disassembly, and the new on standard pen carriages, per improved performance for all installed instruments.

For further information circle No. 6 on literature request card on p. 32h

SUBZERO MACHINE: A new model industrial chilling machine to meet the needs of smaller capacity users has been announced by Deepfreeze Distributing Corp. The new model, W-120, has a capacity of 5 cu.ft., and will maintain temperatures as low as minus 120° F. At this temperature it will remove 500 Btu. per hr., the equivalent of cooling 20 lb. of ste from room temperature to minus

> The W-120 is expected to terest to operate

in every ton if the 020 strip steel actually meas .002" oversize

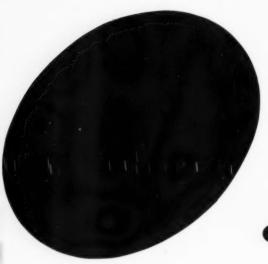
factore loss increases as thickness in Astronomical dis progra discrepana

the precision gauge tolerance of protects you against such costly losses insures maximum practical yield per ton



the Cold Metal Products co.

**FOUNDATIONN 1, OHIO** 



ites your s by testing CMP Co. admets in one aularly

# (1) Low Curbon Cold Rolled Str. a Steel-Colls

- with
- olled

- r best
- (c) mirror
- (d)

- nish); or #3 ke finish pro
  - chrome-nickel -chromium grades
  - (c) High m 125,000# PSI minimum up to 20 where desirab minimum or mor
  - (d) High hardness by special heat treatment
  - (e) Thicknesses .001" and heavier



### (4) Cold Rolled Alloy Strip

- (a) Standard alloys
- (b) #2 regular cold r nirror finish
- (c) Specifications can l requirements in co-tory controlled pro our Labora-

# (5) Tempered Spring Stee

- (a) Scaleless blue
- (b) Tempered and pe (c) Tempered, polish
- (d) CMP Tempered Gauges, Vibrata Band Saws, Ta teel for Feeler ra Main Springs, er Steel

CMP THINSTEEL be ordered direct ill quantities or for the following warefrom the mill, or for emergency service

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nal Products Company of California, 6600 nley Avenue, Los Angeles, California, 'phone ceasant 3-1291

# the Cold Metal Products co.

YOUNGSTOWN I, OHIO

New York \* Chicago \* Indianapolis \* Detroit \* St. Louis \* Las Angeles \* Cleveland

process. Alcoa has also acquired the U. S. patent rights to the Martin hard coating for aluminum from the Glenn L. Martin Co. The MHC finish is similar to the Alumilite coatings in hardness and structure. The Glenn L. Martin Co. reports that the MHC finish has been used successfully in the solution of problems of wear, abrasion, heat erosion, and corrosion in such diversified articles as gears and pinions, turbine impeller blades, nozzles, the leading edges of highspeed airfoils, and leg braces for paraplegics. MHC-finished aluminum has been applied to many parts of Martin aircraft, such as pistons, cylinders, jack-screws, walkways, door mechanisms, and other applications in which the finish has permitted aluminum-for-steel substitutions which have cut weight and operating costs.

For further information circle No. 679 on literature request card on p. 32B

PRECISION CASTING FURNACE: Developed especially for high-speed production of precision castings, this new mechanically-operated Ajax-Northrup induction furnace transfers molten metal from furnace to mold in any pre-set cycle, usually only a few seconds. Typical of high-performance parts being cast with the



new units are jet engine vanes and blades, compressor parts and small ordnance components. Operation is extremely simple. At the end of the melting period — 12 min. for 5 lb. of alloy steel — the preheated mold or investment is clamped directly to the top of the crucible with a specially-fitted holder. Operation of a control lever causes the furnace to rotate to pouring position. The new furnace, made by Ajax Electrothermic Corp.,

is powered by a standard Ajax-Northrup 20-kw. mercury-hydrogen type of converter, and operates at a frequency of about 30,000 cycles. The converter can also be used to power other melting furnaces, or for various types of heating equipment, as for heat treating or brazing.

For further information circle No. 680 on literature request card on p. 32B

THREAD ROLLING MACHINE: First to incorporate the efficient "planetary" principle, the Prutton "Rollmaster" introduces unique engineering features for high-speed thread rolling in a wide variety of metals ranging from nonferrous to hardened and stainless steels. The machine produces threads of class 3 fit at



18,000 to 20,000 pieces per hr., including set-up time. The Rollmaster threads bolts, fetter ring and spiral nails, and does many knurling, marking, serrating, necking and contour operations.

For further information circle No. 681 on literature request card on p. 32B

INSTRUMENT PEN: New industrial instrument pens have been designed by Minneapolis-Honeywell Regulator Co. for their strip-chart electronic instruments. The new pens have removable tips and a new reservoir construction which eliminates flooding. Other advantages are: The



pen operates with decreased pressure on the instrument chart, tending to reduce paper fiber choking; thorough cleaning is made easy by a simple disassembly, and the new design fits on standard pen carriages, permitting improved performance for already installed instruments.

For further information circle No. 682 on literature request card on p. 32B

SUBZERO MACHINE: A new model industrial chilling machine to meet the needs of smaller capacity users has been announced by Deepfreeze Distributing Corp. The new model, W-120, has a capacity of 5 cu.ft., and will maintain temperatures as low as minus 120° F. At this temperature it will remove 500 Btu. per hr., the equivalent of cooling 20 lb. of steel from room temperature to minus 120° F. The W-120 is expected to be of special interest to operators of smaller heat treating departments. The increased use of subzero temperatures for quick and complete stabilization has developed a need for such units in heat treating plants and departments whose size did not necessitate the larger capacity models.

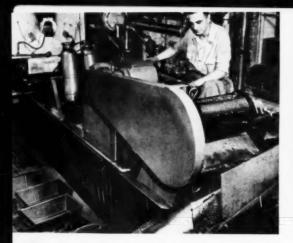
For further information circle No. 683 on literature request card on p. 32B



LIQUID HONING: A new liquid honing machine by Vapor Blast Mfg. Co. has been developed for use in honing tools, broaches, hobs, taps and drills and larger tools like dies and molds. It can be operated from either sitting or standing position.

For further information circle No. 681 on literature request card on p. 3213

BRAZING FLUX FOR TITANIUM: Handy & Harman announces the development of a brazing flux for use in the joining of titanium and zir-



LESS DRAG-OUT... NO SLUDGE. This continuous shaker hearth furnace heat-treats parts at 1.525 F and quenches them in oil controlled between 120 F and 130 F. With the oil formerly used, drag-out was excessive and sludging a constant problem. By switching to Sun Quenching Oil Light, the company reduced drag-out appreciably and eliminated sludging altogether.



SURFACE SPOTTING ELIMINATED. The oil used formerly by this company gave quenched parts a troutlike appearance. It also left traces of smut. Ever since the switch to Sun Quenching Oil Light, parts have come out clean and a shiny blue-black color. Among the materials used by this screw manufacturing plant are: SAE 1037, 3135, 4137, 6850 steels.

# PRODUCTION IMPROVED, COSTS CUT 40% BY SWITCH TO SUN QUENCHING OIL LIGHT

A large New England company manufacturing socket screws and related items was using an expensive oil for quenching. Nevertheless, results were poor, Drag-out was excessive. Heavy sludge deposits accumulated in the tank. Instead of coming out shining and blue-black in color, parts were dirty, and speckled with brownish spots. Obnoxious oil vapors bothered the operators.

The company asked a Sun representative for suggestions and on his advice filled the system with Sun Quenching Oil Light on a test basis; then, after five months' trial, adopted it. Oil costs have dropped 40 percent—an annual saving of \$1,200. Drag-out is less

—with lower oil consumption resulting. Quenched parts come out a clean blue-black. Because of the natural detergency of this product, the system remains clean at all times. Odors are no longer a problem.

Sun Quenching Oils give consistently uniform results. They drain off rapidly, keeping drag-out to a minimum. They do not thicken up and lose their quenching speed. Under normal operating conditions, they do not form sludge and need never be replaced. Sun Quenching Oils, although far less expensive than highly compounded oils, meet the requirements of 95 percent of all quenching operations.

	Sun representative contact me, einformative booklet, "Sun Quenching Oils,"
Z (18118)	
Title	
Title	

TECHNICAL ASSISTANCE AVAILABLE. Sun's engineers are at your service for consultation on quenching-oil matters. If will pary you to utilize the experience they have gained solving a wide variety of problems in other plants.



NO OBNOXIOUS VAPOR ODORS. With the former oil, objectionable odors raised a serious morale problem. The odor of Sun Quenching Oil Light is not unpleasant. A big improvement has therefore resulted in working conditions.

# SUN INDUSTRIAL PRODUCTS

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conium and their alloys. Silver brazing alloys readily wet the titanium which is protected by the flux. Although titanium and zirconium form brittle compounds with most metals and alloys that may be used for brazing, the embrittlement may be minimized by rapid heating and limiting the time at brazing temperature. For this reason, low-temperature brazing alloys are preferred. The new flux is called Special Handy Flux for Titanium.

For further information circle No. 685 on literature request card on p. 32B

TESTING MACHINE: An improved, low-cost universal testing machine of 120,000-lb. capacity is announced by Baldwin-Lima-Hamilton Corp. The hydraulic loading unit is separate



from the indicating and control unit, which isolates recoil from breaking test specimens and permits adjusting maximum or lazy hands with minimum drag. Load (either in tension or compression) is applied upward by an integrated piston and elevating cage. Loading speed can be varied infinitely between 0 and 2 in, per min. Two ranges, 0 to 120,000 and 0 to 30,000 lb., are standard. Any two of six other ranges are available, and three ranges can be provided.

For further information circle No. 686 on literature request card on p. 32B

ALKALINE DERUSTING: Announcement of the development of a new alkaline derusting process for steel, cast iron, malleable iron and other ferrous alloys is made by Enthone, Lie. Because the process is alkaline, it simultaneously cleans and derusts. In one test, complete rust and scale removal was accomplished in 2 min. as against 45 min. for acid pickling. This is important where high-speed pickling of wire or strip must be accomplished. The process is application.

able for derusting without a heat source being available.

The operation of the bath is simple. Parts heavily contaminated with grease should first be degreased. However, light oil is readily removed in the bath. The parts are then immersed in the derusting solution where they are made the cathode for periods varying from a few seconds to several minutes, depending on current density and condition of the surface. A wide range of current density can be employed from five to several hundred amperes per square foot. After derusting, the object is clean and bright. Longer treatment does not result in any attack upon the metal being pickled, Therefore, close watching of the pickling process is not required. One of the chief advantages claimed for the process is due to the fact that it is alkaline and there is no tendency to cause surrounding equipment to be corroded, such as occurs with acid pickling processes.

For further information circle No. 687 on literature request card on p. 32B

COMBINATION GAS-OIL BURNER: Eclipse Fuel Engineering Co. announces the new Fyr-Matic gas-oil burner, designed for industrial and commercial use in applications where both oil and gas are available. Changeover from one fuel to the other is made instantly and automatically by the flick of a switch. This new combination burner makes it possible to alternate the use of fuels back and forth according to availability, economy or suitability, Mixed, natural or L-P gas (800 to 3200 Btu.) or No. 1, 2, or 3 fuel oil may be used in the burner, all operating with equal efficiency. Either gas or oil can be burned without induced secondary air, as the burner is designed to



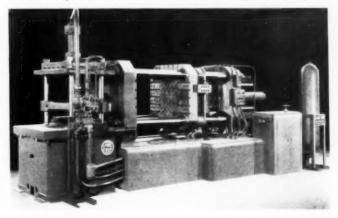
furnish its own air for complete combustion. Positive ignition is assured with either fuel; with oil, direct electric spark ignition is employed; for burning gas, ignition is provided by a gas pilot which must "prove" itself to the electronic safety circuit before the main fuel is admitted to the burner.

For further information circle No. 689 on literature request card on p. 32B

DIE-CASTING MACHINES: The Lake Eric Engineering Corp. has introduced an improved line of die-casting machines, incorporating two exclusive features, the "wedge cam toggle" and the "pressure-pac" injection unit. The former is a self-compensating toggle clamp which automatically takes up clearances in the dies due to contraction and expansion of the molds during production or shut-down periods. The new in-

jection unit facilitates production of denser castings by providing the necessary pressure to feed the shrink or to compress the porosity at the time of solidification of the metal. The new line of machines is available in 10 models, ranging from 100 to 1000-ton capacity, for casting all the usual nonferrous metals and alloys.

For further information circle No. 688 on literature request card on p. 32B



# DISTORTION

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QUALITY
IMPROVED

with a ...



SAE-1095 TRIGGER SPRING

Clean hardened, 350 per load, in 30 minutes at 1500° F. Distortion reduced, cleaning operation eliminated. Wt. per piece — .19 lbs.



SAE-1045 HITCH HOOK

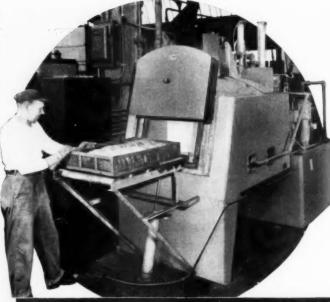
Clean hardened, 60 per load, in one hour at 1600° F. A scale-free and a more rust resistant

finish is produced, cleaning operation eliminated Wt. per piece — 4 lbs.



load, in one hour at 1625° F. Distortion reduced, cleaning and buffing eliminated.
Wt. per piece — 3.1 lbs.





Ipsen T-230 Heat Treating Unit in large Farm Equipment plant. Operator simply loads the unit and sets the heat treating cycle. Work is headled through heat and quench (or cooling) cycle automatically. Change-over from one job to another is lost and simple.

# NEW IPSEN STANDARD AUTOMATIC HEAT TREATING UNIT

Described at left are typical results obtained by a Farm Machinery Manufacturer in clean hardening more than 50 different workpieces on a production basis in an Ipsen Automatic Heat Treating Unit. Controlled, automatic batch processing from heat through quench, combined with sealed atmosphere operations, have also effected important improvements in product quality. For example, highly uniform results are now obtained from load to load which permits more accurate control of wear. Also clean, scale-free, more rust-resistant work is obtained. Further, distortion is held to close limits, which not only speeds production but also simplifies assembly and field service problems.

# Bright Carbonitriding Cuts Processing Time 75%

In addition, 15 different workpieces requiring case depths ranging from .015 -.035" are also automatically processed in the Ipsen. On these jobs, the Ipsen exclusive bright carbonitriding process is employed. This method cuts processing time as much as 75%, and improves delivery schedules. Workpiece distortion is also accurately controlled, and extra handling and cleaning operations are eliminated. In use for more than nine months, the unit has operated on a 24 hour schedule, with no downtime for maintenance.

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pharmacist a specialist who has the know-how. So it is with fluxes Special Chemicals engineers have been specializing in the formulation and production of hard solding and brazing fluxes for more than 20 years. That's why you can depend on KWINFELV for better metal joining of ferrous and non-ferrous metals at lower cost. Works neffectly with

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Type of brazing alloy		
Type of heat application		
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City	Zone	State

# What's New

IN MANUFACTURERS'
LITERATURE

690. Abrasive Belt Machines

30-page illustrated booklet of case histories. The Parter-Cable Machine Co.

691. Air-Gas Mixer

Engineering and application data on series "LP" air-gas proportional mixer is available in Bulletin L-300. Edipse Fuel Engineering Co.

692. Alloy Selection

New 24-page booklet. "Long-Wearing Machinery Parts shows sizes and shapes of parts made of Haynes alloys. Haynes Stellite Co.

693. Alloy Steel

New 16-page, pecket-size booklet entitled "Republic Alloy Steels and How to Get the Most Out of Them" contains seven case histories selected from widely varied fields to demonstrate the versatility of alloy steels. Republic Steel Corp.

694. Alloy Steel

Booklet on Carilloy steel tells how No. 4150 and others provide toughness, strength and lightweight durability under trying conditions of service. U. N. Nicel Co.

695. Alloys

28-page bulletin describes alloys available including terro-alloys containing titanium and boron, pure metallic titanium and zirconium, and zirconite. Titanium Alloys Mfg, Co.

696. Alloys, Fabricated

Catalog available showing cost-cutting infricated heat treating equipment for higher payloads and better quality. Rolock, Inc.

697. Aluminum Forgings

New book covering relation of forging design to die sinking and relation of forging design to the manufacturing process. Section on metallurgy gives confinercial alloy compositions, physical properties and tolerances. Aluminum Co. of America.

698. Annealing

Booklet on burner especially designed for annealing furnaces and other uses where flame impingement is not permissible. Bloom Engineering Co., Inc.

# 699. Anti-Carburizing Paint

Descriptive literature is available on paint which prevents carburizing or hardening of certain spots on steel parts. Case Hardening Service Co.

700. Arc Welders

Illustrated booklets available on both A-C and D-C are welders. Contain data and diagrams on construction and uses. Westinghouse Electric Corp.

701. Austempering

Article on modified austempering of cylinder liners at Jacobs Aircraft Co., from current issue of "Tips and Trends", Ajax Electric Co.

702. Automatic Polishing

14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. Murray-Way Corp.

703. Barrel Finishing

Bulletin describes new chemical in paste form for descaling, roughing, deburring, cleaning, and finishing noniterrous parts by barrel tumbling. Blue Magic Chemical Specialties Co.

704. Belts

Illustrated catalog 47P describes metal materialhandling belts. Ashaorth Bros.

705. Bimetal Elements

64-page catalog written e-pecially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device, W. M. Chace Co.

706. Blast Cleaning

16-page booklet analyzes basic problems involved in blast cleaning and peening operations. Measures effectiveness of metal abrasives. Hickman, Williams & Co.

707. Brazing

Rulletin 20 tells of advantages of Fasy-Flo silver brazing alloy. 24-page bulletin gives information about joint design and fast production methods. Handy & Harman.

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- Special provisions to minimize parasitic thermal emf's —including automatic compensation of slidewire thermals and gold contacts in galvanometer key.
- Exceptional convenience in reading and adjustment.
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   This standard laboratory potentiometer is also well suited for meter calibration, for checking portable potentiometers, and for other critical measurements of D.C. potentials requiring exceptionally high

Described in Bulletin 270

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708. Brazing

50-page text GEA-3193 describes the methods and applications of electric-turnace brazing. General Electric Co.

709. Brazing Alloys

New 8-page illustrate booklet explains uses of plues-copper and plues-silver extruded alloys for torch brazing, turnace brazing and resistance brazing of copper, brass and bronze. Also data on brazing flux for ferrous and nonferrous metals. Westinghouse Electric Corp.

710. Brazing, Silver

48-page, pocket-size manual on all aspects of diver brazing applications and problems. The American Platinum Works.

711. Brazing Washers

Free sample of silver brazing alloy pre-former washer coined from wire. Lucas-Milhaupt Engineering Co.

# 712. Bronze

Vol. 8. No. 1, of the Lavingot technical journal contains discussions of effects of various elements in manganese bronze. R. Lavin & Sons, Inc.

# 713. Burners

Burner Catalog B-11 lists full line of standard burners from ribbon flame burner to simple, effi-cient soldering from, Dimension tables, schematic drawings, output charts. C. M. Kemp Mfs. Co.

# 714. Camera Microscope

Complete information on construction, opera-tion and special features of MEF universal metal-lurgical camera microscope. If m. J. Harker & Co., Inc.

# 715. Carbon Control

Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. Leek & Northrag Co.

# 716. Carbon and Sulphur Analysis

Folder, punched for insertion in standard three-ring binder, describes induction turnaces for carbon and sulphur analysis. Laboratory Equipment Corp.

# 717. Case Hardening Compound

Technical data on Aerocase, case hardening compound. American Chanamid Co.

# 718. Castings, Centrifugal

12-page illustrated bulletin on centrifugal cast-ings of steel in permanent metal molds. Letanos Sieel Foundry.

# 719. Chromium Stainless Steels

Folder gives applications of various chromium stamless steels. Includes table of analyses and properties. Lebanon Steel Foundry.

720. Cleaning Bulletin 214 gives full details, specifications and actual performance on laster blast cleaning with Rotoblast barrels. Panishors Corp.

# 721. Cleaning

Information on new deaning process that uses emulsion cleaners, based on petroleum and addition agent 240. This two-phase bath provides unique cleaning in conjunction with a thin displacement film that removes foreign particles. Northwest Chemical Co.

722. Cleaning

New booklet entitled "Your Metal Rearmament Products" contains outline of most efficient methods of handling, as well as cleaning, metal products for detense. Alrey-Ferguon Co.

# 723. Cleaning and Buffing

"Barrel Finishing of Metal Parts" contains interesting data on barrel deburring, as well as methods of removing many kinds of burrs from swung, dulling, milling and stamping operations. Mggmax Chemical Co.

# 724. Cleaning and Finishing

Attractive 12-page, well-illustrated catalog \( \lambda \) -652 gives the complete story on planning industrial mushing systems and shows many installations of cleaning and picking machines operating in large metalworking plants. R. C. Maion Co.

# 725. Cleaning Equipment and Materials

Series of attractively illustrated bulletins inform-concerning dry cleaning process, degreasers, metal-parts washers, degreasing solvents, emulsion and alkaline cleaners, and tust proofing compounds. Detect Cop.



few of the investment castings produced by Casting Engineers, Inc. at savings of at least 50% under cost of machining - a rate of 2 investment castings for the price of 1 machined part!

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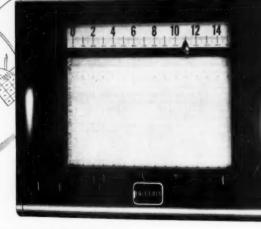
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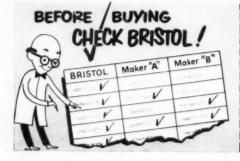
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Booklet No. A-801 describes Heat Prover, an instrument which measures combustion efficiency of any type furnace using any form of fuel. Cities Service Oil Co.

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12-page catalog describes properties, sizes and weights of continuous cast bronzes. American Smelling & Refining Co.

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4-page descriptive and illustrative bulletin on continuous sampling monitor—a new device to simplify quality control. Explains operation, con-struction, range. General Electric Co.

# 730. Coolant

Eight case histories on use of company a coolant concentrate in grinding, tapping, threading, turn-ing, drilling and forming, Master Chemical Corp.

# 731. Copper Alloy Forgings

12-page booklet provides practical, comparative illustrations on die-pressed copper alloy forgings. Contains tabulation of physical properties of copper and copper alloys suitable for forgings. The American Brass Co.

# 732. Copper Alloy Tubes

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6-page illustrated tolder gives useful data on seamless copper tubing. Chart teaturing safe working internal pressures for both amuscled copper and hard copper seamless tubing. Pean Brans & Copper Co.

# 734. Corrosion-Inhibiting Metal Waxes

Data sheet of playsical characteristics and application methods for solvent-type and emulsion-type metal waxes for protective limithes. S. C. Johnson & Son, Inc.

# 735. Corrosion Resistance

Single-page technical discussion of factors affecting corrosion resistance of stainless steels. Cooper Allay Foundry, Co.

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32-page bulletm of case lustones on use of all-purpose base in various machining operations. E. F. Houghton & Co.

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New bulletin on "Gult Electro Cutting Oil" which contains larger percentage of active sulphur ingredient, recommended for toughest machining jobs. Gulf Oil Corp.

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# 739. Cutting Oils

Shop notebook giving important tacts on right cutting fluid for any machining operation. D. A. Sheari thi Co.

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Economies and characteristics of cleaning and penning with cut-wire shot are described in a 4-page tolder. Cleseland Metal Abrasise Co.

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Folder on water demineralizer for laboratories and electroplaters. Eberback Corp.

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Illustrated tolder gives advantages and various teatures of sodium hydride positive descaling. E. I. duPont de Vemours & Co.

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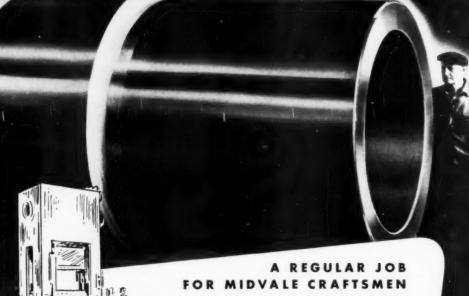
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# 746. Electric Furnaces

Bulletin No. 473 describes rocking, automatic melting machine for various ferrons and nonferron-alloys. Detroit Electric Furnace Div.

# 747. Electron Microscope

The new table model RCA electron microscope is described and illustrated in a 12-page booklet. Radio Corp. of America.

# 748. Electropolisher

A bulletin on the theory and practice of elec-trolytic polishing of metallurgical samples includes description of Buehler-Waisman electropolisher,

# 749. Extruded Aluminum

40-page illustrated brochure on use of extruded aluminum for moldings and other applications. Youngstown Manufacturing, Inc.

# 750. Fabricating Stainless

48-page illustrated booklet furnishes data on many types of fabrication. Includes machining pickling and welding. Republic Steel Corp.

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Illustrated folder describes facilities for mass production of defense prime contract and sub-contract work. Charles T. Brandt, Inc.

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New 4-page, two-color bulletin describes in detail the entire line of fridite fuishes for non-ferrous metals. Also includes section ARP process chemicals such as bright hardeners for zinc and cadmium plating and other specialties. Allied Research Products, Inc.

# 753. Flow Meters

Catalog C-12 gives complete line of meters an accessories for measuring pressure, vacuum an differential pressure of liquids and gases. Meriar Instrument Co.

# 754. Forging Steel

Bulletin 31 furnishes helpful information on stainless forging problems and includes specific data on chemical composition of alloy steels. Timken Roller Bearing Co.

# 755. Forgings

Catalog GI illustrating types of upset and hammer lorgings manufactured for various appli-cations. The Commercial Shearing & Shamping Co.

# 756. Forming

Special bulletin of metal spinning, stamping and tabricating facilities. C. A. Dahlin Co.

# 757. Furnaces

Bulletin 435 describes new turnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated, W. S. Rockwell Co.

# 758. Furnaces

Production electric heat treating furnaces are described in Bulletin 1951. Types include those for continuous brazing and sintering, bright an-nealing, forging and general heat treating. Harper Electric Furnace Corp.

# 759. Furnaces

Catalog W-2 for descriptive matter on tool hardening equipment Model VP (vertical type) and Model 2V. Sentry Co.

### 760. Furnaces

Folders describe chain belt conveyor turnace, radiant tube gas heated, oil or electrically heated. Also other production (urnaces. The Electric Furnace Co.

# 761. Furnaces

Heavy-duty box farmaces that provide uniform temperatures for hardening production tools are described in bulletins HD-341 and HD-441. Heri Ducy Electric Co.

# 762. Furnaces

Eight sizes in gas or electric models as well as conveyorized and batch or pot-type furnaces in bulletin 84P. Despatch Oren Co.

# 763. Furnaces

New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hard-ening. Here Daty Electric Co.

# 761. Furnaces

Literature describing the use of Marshall tubular furnaces for constant and uniform temperature, intrinshed in types suitable to your needs. Also radial brackets in stationary and compensating types. Marshall Products Co.

# 765. Furnaces

16-page booklet "Proven Heat-Treating Effi-ency" containing attractive four-color illustra-ons displays complete line of furnaces. Loftus naineering Corp.

# 766. Furnaces

Complete "Buzzer" catalog available describing Buzzer high-speed gas furnaces designed primarily for heat treating high carbon and alloy steels and also atmospheric pot hardening furnaces for salt, cyanide and lead hardening. Charles A. Homes. Inc.

# 767. Furnaces

38-page illustrated bulletin, "Harnessing Heat", deals with uses of 14 types of gas and electric intraces. Section on controlled atmospheres. Westinghone Electric Corp.

# 768. Furnaces, Annealing

Illustrated booklet on continuous vertical strip innealing furnaces, both single and multiple strand. The Drever Co.

# 769. Furnaces, Continuous Annealing

Folder of performance and cost data on radiant the and roller hearth turnaces for heat treating. the Gas Machinery Co.

# 770. Furnaces, Melting

Catalog on Heroult gantry-type electric melting furnace with patented root-ring to assure speedy and simple bricking and eliminate skew shapes. American Bridge Co.

# 771. Gages

Bulletin BG-MP describes highly accurate beta radiation gage used for thickness measurements. One model measures thickness of material accessible from one side only. Tracerlab, Inc.

# 772. Galvanizing

Reprint "Modern Hot-Dip Galvanizing" deals with dress formation as a cause of zinc waste. Detailed miormation on zinc ammonium chloride type of flux. Hanson-Van Winkle-Munning Co.

# 773. Gas Analyzer

Instrumentation data sheet 10.15-3a describe indicating and recording flue gas analyzer which gives continuous record of combustion analysis Minneapolis-Honeywell Regulator Co.



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The Extrudite Process opens the door to faster, less-wasteful cold forming of steel and other metals. This Detrex development chemically interlocks a dry, heat-resistant lubricant to the work surface . . . metal-to-metal friction is prevented even during the most severe working conditions.

Savings are tremendous on operations such as wire and tube drawing, deep drawing, cold heading and room temperature extrusions. To name but a few of the benefits; operations are speeded up on present equipment, tooling lasts longer, parts are produced with less scrap and many process anneals and chemical treatments are eliminated.



Details of the Extrudite Process and its advantages are contained in this informative bulletin. Send for yours today, there is no obligation. The Extrudite Process consists of a special phosphate coating which becomes integral with the work surface. Then a compatible lubricant is applied which drys to a tough, crystalline lubricating film. Thus the treated metal is clean and easy to handle.

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774. Gas Carburizer

Bulletin 1212 illustrates and describes No. 4 todary gas carburizer for use with small parts. American Gas Furnace Co.

775. Gear Hardening

Folder on application of induction heating to high-production hardening of gears. Westirchouse Electric Corp.

776. Graphite Electrodes

Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. Great Lakes Carbon Corp.

777. Grinding Titanium

Article on grinding wheels and techniques for titanium, from "Grits and Grinds", Norton Co.

778. Hand Pyrometer

Data sheet GEC-836 on hand pyrometer with scale ranges of 0 to 500 and 0 to 1500° F. General Electric Co.

779. Hardfacing

New wall chart which details the proper hard-tacing rod for the job. American Manganese Steel Die.

780. Hardfacing Rods

Five bulletins cover company's complete line of hard facing alloy rods. Victor Equipment Co.

781. Hardness Tester

Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of inetallic and nonnetable ma-terials. Also included is bulletin DH-7, outlining experiences in various fields. Wilson Mechanical Instrument Co.

782. Heat Exchangers

Bulletin No. 35-76C and illustrated tolder No. 250 discuss equipment for use in queuching operation and other uses. American District Steam Co.

783. Heating Elements

Bulletin H gives detailed information on AT-type momentallic electric heating elements, including tables for a wide variety of sizes, available,  $Globar\ Div.$ ,  $Carborundum\ Co.$ 

784. Heating of Plating Baths

Blustrated builtin on unit heat exchangers designed to maintain working temperature of mixel platting solutions by continued heating or cooling in the same unit. Industrial Filler & Pump Mg. Co.

785. Heat Treating

Catalog 116 contains 72 pages of tactual heat-treating data for carburizing, cyanide hardening, brazing, austempering, and annealing processes. Ajax Eletric Co.

786. Heat Treating

Handy vest-pocket data book has 72 pages of charts tables diagrams and factual data on late steel specifications, heat treatments, etc. Sunbeam In-dustrial Furnace Div.

787. Heat Treating

Bulletin 120 tells how Nagara Acto Heat Exchangers provide better heat control in quenching bath thus protecting physical properties and saving on water and piping equipment. Viagara Bloom Co.

788. Heat Treating

Ipsenlab periodic sheets show case histories on bright hardening, annealing and carburizing. I poen Industries, Inc.

789. Heat Treating

40-page booklet on facilities for tool heat treat, bright hardening of stainless, case hardening, machine quenching cleaning straightening and inspection. Commercial Steel Frenting Corp.

790. Heat Treating

24-page Story of Malcomizing describes sur-tace hardening of stainless steels. Includes case histories. Lindberg Steel Treating Co.

791. Heat Treating

Booklet describes complete diversited tacilities for steel, aluminum and magnesium heat treating. Pearson Industrial Steel Treating Co.

792. Heat Treating Atmospheres

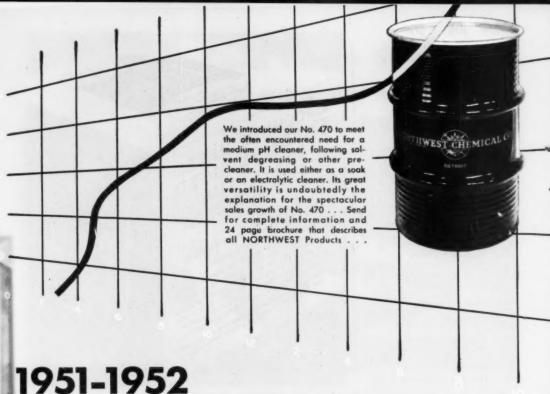
Bulletin SC-155 on prepared atmospheres for all heat treating requirements. Surface Com-

793. Heat Treating Baskets

Baskets designed for your individual needs in handling parts. All types of travs, fixtures, retorts and carburizing boxes are described in catalog 16. Stamwood Corp.







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#### 794. Heat Treating Fixtures

Information on complete line of standard car-burizing carriers that will handle odd-shaped parts of every type thru carburizing and quenching to huisburg. Pressed Steel Co.

#### 795. Heat Treating Pots

New bulletin T-205 lists 118 patterns available in Thermalloy heat treating pots, both round and rectangular, X-rayed and pressure tested for sound and economical service. Electro-Alloys Div.

#### 796. High Temperature Alloys

"Inco High Temperature Work Sheet" pro-vides valuable information and suggestions for solving high temperature problems in design and production. International Nickel Co.

#### 797. Hydraulic Presses

Bulletin 147, "Practical Facts About Hydraulic Presses", an informative guide for the user of all types and sizes of hydraulic presses. Lake Erie Engineering Corp.

#### 798. Identifying Metals and Allova

Booklet of procedures for rapid identification of more than 125 metals and allows. The Inter-national Nickel Co., Inc.

#### 799. Identifying Stainless Steel

Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. Carpenter Steel Co.

#### 800. Induction Heating

Catalog MP4 describes portable high trequency induction beating unit for brazing hardening, and melting. Level High Frequency Labor. Inc.

#### 801. Induction Heating

"Induction Heating . . . the machine tool that makes tall stories come true" presents case his tories of how induction heating has increased production, reduced space and cut costs. Westing-more Electric Corp.

#### 802. Induction Heating

Bulletin 1440 birnishes full details on the "Greeklite" system for safety control through the use of oversized components built into every unit for longer service life and miniterrupted produc-tion. Lindberg Engineering Co.

#### 803. Induction Melting

Bulletin describes the application of induction heat to melting of metals. Ohio Crankshaft Co.

#### 801. Industrial Planning

#### 805. Instruments

"Tomorrow Is Today is a new brochure telling of the many contributions of instruments to industrial processing. Minneapolis-Honeywell Reg-solutor Co.

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Capacitrals and capacilines are described in bul-letins PC-1 and CL-1. Wheelco Instruments Co.

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New list of publications available on advantages and properties of ductile iron, along with special applications and 100 authorized foundry sources now producing it. International Nickel Co.

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Series of data sheets give full information on complete line of laboratory furnaces for numerous metallurgical operations. Boder Scientific Co.

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The uses of colloidad graphite for hot metal-working operations deep piercing, casting, forg-ing, stretch-forming and wire drawing operations) are explained in bulletin No. 426-10D. Achieon Colloids Corp.

#### 811. Magnesium

41-page booklet on processing and properties of wrought torms of magnesium. Includes 31 tables. White Metal Rolling & Stamping Corp.

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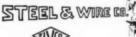
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product, dimensional accuracy and type of surface finish required. Send along a print if you like.

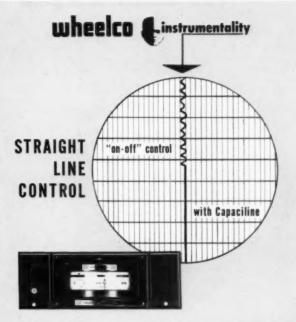
The B&W Technical Staff will supply objective recommendations and, if you desire, your regional B&W Tube Representative -Mr. Tubes-will step in to help interpret your needs to the home office. Bulletin TB-324 gives an idea of what can be done with fine tubing. Write for it.

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Manufacturers of Capacilog strip chart recorders, Flame-otrol combustion safeguards 813. Marform Deep Drawing

Catalog No. L-79-641 describes pressure control mechanism for use in the Mariorm deep drawing process. Lowey Construction Co.

814. Metal Cutting

New 64-page catalog No. 28 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. Martin-dale Electric Co.

815. Metal Finishing

New check list available on sixty products and processes for metal finishing, including a new acid addition agent, a cleaning and pickling agent combined, a new complete inhibitor and a new rust-preventive compound. Enthone, Inc.

816. Metallograph

Revision of catalog will include the new metal-lograph with polarizing and phase attachments. Now in preparation for early release. American Optical Co.

817. Metallographic Polishers

Bulletin 90 shows various models of metal-lographic specimen polishers. Eberback Corp.

818. Metal Spraying

Article "Metallizing — What It Is. What Does", in current issue of "The Metallizer Metallizing Co. of America.

819. Metalworking Lubricant Data sheet on solid waxes in stick form for use as lubricant in sawing, threading, drilling, tapping spinning and grinding. S. C. Johnson & Son, Inc.

820. Micrographic Equipment

6-page bulletin on a universal camera microscope giving plate magnifications from 4 to 3000×. Full details on optics and accessories included. Opplem Co.

821. Microscopes

Well-dilustrated 22-page booklet on Dynoptic Labroscopes, featuring ball bearings and rollers throughout the focusing system as well as low position fine adjustment with low controls that enable the operator to manipulate other controls more easily. Basich & Lomb Optical Co.

822. Modulus Determination

Data sheet on equipment for determination of modulus of elasticity by sonic method that measures resonance frequency of masses weighing up to 1500 lb. Electro Products Laboratories, Inc.

823. Moly-Sulfide Lubricant

50-page booklet listing 154 applications for ody-sulfide lubricant with specific information each. Climax Molvbdenum Co.

824. Nickel Alloys

Booklet, "Hastelloy Nickel-Base Alloys", gives full details of their use for fabricating corrosion-resistant screen, cloth and baskets and for meal spraying and hard facing. Haynes Stellite Co.

825. Nondestructive Inspection

Data available on electronic inspection equip-ment, demagnetizers and comparators for sorting. Magnetic Analysis Corp.

826. Photography

Catalog, "Kodak Sensitized Materials for the ientific and Industrial Laboratory", tells of secial films, plates and pellicles, transmission rves of filters and filter combinations commonly sed in photography. Eastman Kodak Co.

827. Piercing

A calculator of the slide-rule type for determining the required pressure (in tons) for piercing a given size hole in any thickness and type of metal. Ward Machinery Co.

828. Piping and Tubing

New 68-page book is a practical treatise on pipe and tube making, answering many pertinent ques-tions on tube mill operations and production. Foder Co.

829. Plating Barrels

4-page folder illustrates and describes equip-ment designed to handle any barrel plating problem quickly and easily with a unique contact arrange-ment for maximum current distribution. Damiels Plating Barrel & Supply Co.

830. Plating Rectifier

Booklet 127 describes d-c. power requirements relectroplating, electropolishing and electronements. Equipment recommendations; descripons, drawings and photographs of company ac of selenium rectifiers. Bari-Messing Comp.

831. Potentiometer, Portable

Bulletins 270 and 270-A describe portable tentiometers in a selection of ranges up to 6 volts. Rubicon Co.

832. Pots

Bulletin N-1 tells of pressed steel pots for lead, salt, cyanide, oil tempering and metal melting. Eclipse Fuel Engineering Co.

833. Power Brushes

New 76-page catalog No. 210 simplifies selection of power brush for the individual job; contains numerous colored illustrations of various types of brushes in operation. Osborn Mfg. Co.

834. Precision Casting

12-page, illustrated booklet on precision casting with emphasis on the most widely used equipment and supplies. Check list of applications in various fields included. Alexander Saunders & Co.

835. Precision Castings

Illustrated folder, "Cost Reduction Through Investment Casting", shows diversity of parts to which process applies. Casting Engineers, Inc.

Press owner's manual contains complete rating and maintenance instruction for lat esign straight-side double-crank presses. E.

837. Product Information

Entirely new "Product Information File" in-torms, comprehensively, on time-tested industrial germicides and fungicides. Tells how to bring effective, economical microbial control to plants. The Due Chemical Co.

838. Protective Chemicals

Quick reference list of rust proofing, p ouding and metal protective chemicals is inter or all fabricators of steel, zinc and alum roducts. American Chemical Paint Co.

839. Protective Coating

Bulletin 600 on phenolic coating resin for pro-tecting steel against corrosion. Carboline Co.

840. Pyrometer

Catalog No. 180 gives details about surface pyrometer which gives surface and subsurface tem-perature readings. Pyrometer Instrument Co.

841. Pyrometers

Bulletin GEC-713 and Bulletin GEC-714 describe line of pyrometers and thermocouples. General Electric Co.

842. Pyrometer Wires

Chart of color codes, calibration symbols, thermo-elements of thermocouple and extension wires for ISA, U.S. Military and Aeronautical specifications, Thermo Electric Co., Inc.

843. Quenching Oil

New technical bulletin F-8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. Park Chemi-cal Co.

844. Quenching Oil

Booklet. "Sun Quenching Oils", tells of advan-tages of this line of oils for use in the quenching process. Sun Oil Co.

845. Radiography

Bulletin 400-310 on self-contained X-ray unit for mass production inspection of parts. Westing-house Electric Corp.

846. Radiography

18-page booklet describing company's line of ndustrial X-ray units in range of power up to one million volts. General Electric X-Ray Corp.

847. Recording Meters

New 28-page bulletin E-1111 describ 500 recording voltmeters and ammet special emphasis on newly-developed mo measuring mechanism. Complete data of and specifications of various models for ps and portable use. Bristol Co.

848. Refractories

Revised bulletin entitled "Lumnite R oncrete" discusses latest available in on refractories and heat-resistant concret nite Dir., Universal Atlas Cement Co.

849. Refractories

Form 1409 describes the new Norts stabilized zirconia, ideal refractory for linings, metal melting, thermal insulation for firing titanates and electric heater of Norton Co.

850. Refractories

20-page booklet gives technical inform a basic nature on super refractories, text, charts, tables, illustrations and ap data. Carborundum Co., Refractories Dra

851. Refractories

New 12-page illustrated brochure prese ts for casting special refractory sho ducts for gunning and slap troweling ns, for services through 3000°F. Manville

852. Refractory Mixes

Well-illustrated 16-page bulletin No. vides important data on properties and tions of Sillimanite super-refractory mixes and patches. Chas. Taylor Sons Co

853. Resistance Thermon

36-page catalog and buyers' guide fine of resistance thermometers. Include tabular guide to selection. Leeds & Nov.

854. Resistance Welding 6-page brochure "Spot and Seam W. Aircraft Construction" features Northrop applications. Sciaky Bros., Inc.

855. Rhodium Plating

Directions for rhodium plating, with preference to its use as replacement for plating metals. Baker & Co., Inc.

856. Rust Preventive

Technical information available on a phate-type rust preventive conforming to specifications. American Chemical Pain

857. Salt Spray Test Cab Illustrated bulletin describing test cal-forming to Spec. QQ-M-151a for corrosic in salt-fog or humidity-laden atmosphere trial Filter & Pump Mfg. Co.

858. Saws

Catalog 49 describes complete line cutting saws, covering 35 models in types, including fast, automatic produc hydraulic back-saws and widely used st saws. Armstrong-Blum Mfg. Co.

859. Silica Cement

Illustrated folder on use of silica c laying silica brick in various types of Harbison-Walker Refractories Co.

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### **HEAT TREATING FURNACES**

FOR UTILITY AND PRODUCTION — HARDENING, TEMPERING, ANNEALING, NORMALIZING, STRESS RELIEVING, ALUMINUM TREATING, ETC.

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Let Your New Furnace Pay For Itself In Four Months Through Increased Production.

Improve Surface Appearance and Quality . . . Avoid Excess Scale and "Burned" Work.



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#### 860. Silicone-Base Finish

New brochure on silicone-base heat-resistant finish is now ready. Midland Industrial Fin-ishes Co.

#### 861. Soldering Aluminum

Article on latest techniques and materials de veloped for soldering aluminum, from "Reynold Technical Advisor". Reynolds Metals Co.

#### 862. Soldering Equipment

8-page brochure on soldering and brazing equip-ment describes new Mogul soldering gun and shows its applications to production-line soldering and brazing. Metallizing Co. of America.

#### 863. Spectrographic Analysis

Article on quantitative spectrographic analysis of zinc die-casting alloys, from current issue of Spectrographer's News Letter. Applied Research Laboratories.

#### 864. Spectrophotometer

letin B-211 illustrates junior-size spectro-meter for identifying and measuring solution tuents in analytical or production labora-Harshus Scientific Div.

#### 865. Spring Steel

Handbook describes various spring steels and gives tolerance tables, heat treatment and physical property tables and labrication data. A. R. Purdy Co., Fre.

#### 866. Spring Wire

Detailed information on Pittsburgh oil tempered spring wire to help solve coiling, knotting, forming and twisting operation problems, Pittsburgh Steel Co.

#### 867. Stainless Castings

28-page full-color industrial fantasy, "Alloys in Cooperland", captures the spirit of Lewis Carroll in describing how stainless steel castings are made. The Cooper Alloy Foundry Co.

#### 868. Stainless Steel

Weekly lists with analyses of all plates in stock and latest data. G. O. Carison, Inc.

#### 869. Stampings

Illustrated brochure on variety of stampings made by company. The Commercial Shearing Stamping Co.

#### 870. Stampings

26-page booklet contains reprint of paper on "How Modern Stamping Techniques Can Help Conversion". Leake Stamping Co.

#### 871. Steel, Aircraft

New printing "Aircraft Steels" booklet which includes revised military spees to August, 1951, Also sizes and analyses of aircraft steels carried in stock, Joseph T. Ryerson & Son, Inc.

#### 872. Steel Bars

New wall chart of 275 different grades of stand-ard, special and alloy steel bars shows chemical analyses and other data. LaSalle Steel Co.

#### 873. Steel, Low-Alloy

April, 1952

Booklet on Hi-Steel, which has nearly twice the orking strength of ordinary steels plus the bility to stand up under impact loads. Inland

#### 874. Steel, Low-Alloy

Well-illustrated 8-page folder on N-A-X low-alloy steels lists physical properties and test specifications. Great Lakes Steel Corp.

#### 875. Straightening Presses

Folder on hydraulic straightening presses with capacities up to 25 tons. Anderson Bros. Mfg. Co.

#### 876. Stud Welding

12-page manual prepared to aid designers and production engineers in the fast, economical solu-tion of fastening problems. Specifications, selec-tion guide included. Nelson Stud Welding Dir.

#### 877. Temperature Controller

Data sheet on compact input controller and indicating potentiometer, which can be set to regulate current input anywhere from 5 to 100% time on. Thermo Electric Manufacturing Co.

#### 878. Temperature Controls

New catalog G-17 describes temperature control instruments. Burling Instruments, Inc.

#### 879. Temperature Regulator

Folder giving complete specifications of electrically operated two-position, on-off temperature regulators. Barber-Colman Co.

#### 880. Testing

Bulletin on mechanical and nondestructive test-ing and on certification in accordance with pro-cedure set up by the American Standards Associa-tion. American Standards Testing Bureau. Inc.

#### 881. Testing Machines

Eight-page folder illustrates current Amsler machines for tests in tension, compression, torsion, shear, fatigue, bending and ductlifty. Separate bulletins on wear testing and testing of miniature samples. Buehler, Inc.

#### 882. Thermocouples and Pyrometer Accessories

56-page book comprising a User's Manual, illustrated Buyers' Guide with specifications and prices and thermocouple calibration data. The Brital Co.

#### 883. Thermometers

New catalog 6020 describes compact approach to time-temperature control of operations such as annealing. Describes new instrument that com-bines as many as six functions from a standard sized instrument case. Minneapolis-Honeycell

#### 884. Thickness Gage

A 12-page illustrated brochure describes two new model absorption and backscatter beta gages for the determination of weight per unit area of sheet materials. Tracerlab, Inc.

#### 885. Tools, Stellite

Tool manual and catalog describes four different grades of cast cutting tool alloys. Gives physical mechanical and chemical properties of alloys to help in selecting right tool alloy for various cutting operations. Haynes Stellite Co.

#### 886. Tool Steel

Circle "M", Star-Mo and Van Chip are three high speed steels described in folders covering mechanical and heat treating data and applica-tions. Firth Sterling Steel & Carbide Corp.

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Name

Company Address

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Postcard must be mailed prior to July 1, 1959-Students should write direct to manufacturers.

#### 887. Tool Steel

86-page pocket-size handbook on application and heat treatment of 27 grades of tool and disteels. Ziv Steel & Wire Co.

#### 888. Tool Steel

Information on Warplis products, stock size and price folders will be sent on request, along with name of nearest distributor, Pittsburgh Tool Steel Wire Co.

#### 889. Tool Steel

Stock list of available tool and die steels. Reliable Steel Co.

#### 890. Tool Steel

Service bulletins, issued regularly, give informa-tion on tool steel selection, treatment and use Carpenter Steel Co.

#### 891. Tool Steel Selector

Handy, clearly printed, easy-to-use tool steel elector will be furnished on request, Cracible iteel Co. of America.

#### 892. Tube Fabrication

Concise case histories, production stories and equipment descriptions on tube fabrication from "Pune Engineering News". Pines Engineering Co., Inc.

#### 893. Tubing

42-page "Handbook on Cold Drawn Butt Welded Mechanical Steel Tubing" discusses proc-essing, utility and types. Illustrated. Many useful tables. Pittsburgh Tube Co.

#### 894. Tubing

For full information on analyses available, pro-ction limits, commercial tolerances, temper signations and product descriptions of seamless of weldrawn tubing, send for bulletin 32. Superior

#### 895. Tubing

New illustrated catalog shows typical applica-tion of electrical weld steel mechanical tubing. Useful engineering charts. Brainard Steel Co.

#### 896. Tubing Chart

A chart covering the range of sizes of electric resistance welded tubing produced by company. Babcock & Wilcox Tube Co.

#### 897. Turbo-Compressors

Bulletin No. 107-C gives a variety of experien p pneumatic engineering and No. 126-A describ-he turbo compressor, listing more than 160 stan rd capacities. Spencer Turbine Co.

#### 898. Ultrasonic Testing

Commercial services using reflectose reflectogage are described in bulletin Sperry Products, Inc.

#### 899. Vacuum Metallurgy

Bulletin entitled "National Research Corp. and Vacuum Metallurgs" gives brief resume of the vacuum metallurgical operations and background of this company and of the research and develop-ment facilities and services available to the metal-lurgist. National Research Corp.

#### 900. Weld-Rod Stabilizer

Four-page bulletin on low-hydrogen electrode stabilizer. Includes complete specifications of com-pany's equipment for dehydrating mineral shielding on low-hydrogen electrodes. Feed C. Archer, Inc.

#### 901. Weld-Through Sealer

Data sheet and sample of scaler that resists heat and pressure of spot welding without splattering and burning. Minnesota Mining & Manu-

#### 902. Welding

New illustrated catalog describes gun, head and wires for automatic welding. On-the-job illustrations of applications. Air Reduction Sales Corp.

#### 903. Welding With Bronze

Eight-page reprint. "Jobs You Can Do With Bronze Electrodes", describes techniques and choice of bronze electrodes for welding various copper, steel and cast iron subassemblies. Ampeo Metal, Inc.

#### 904. Wire

Catalog 100 lists grades, sizes and compositions of standard wires and specialties such as flat wire and bookbinding and stitching wire. Seneca Wire &  $Mf_k$ , Ca,

#### 905. Wire, Nonferrous

4-page folder contains wire gage and footage chart and information on beryllium copper, phos-phot bronze, nickel silver, brass and aluminum wire. Little Falls Alloys, Inc.

#### 906. X-Ray Apparatus

Illustrated booklet describes XRD-3 X-ray dif-fraction equipment with its variations to fit the needs of each application. General Electric X-Ray Corp.

#### 907. X-Ray Inspection

Bulletin 400-520 on jib-crane unit for applica-tions where horizontal and vertical travels of standard tubestand are inadequate. Westinghouse Electric Corp.



Rex & High Speed Steels Peerless Hot Work Steels Halcomb 218 Chro-Mow ® Sanderson Carbon Tool Steels Ketos ® **Airkool Die Steel** Airdi 9 150 Nu-Die V Die Casting Steel CSM 2 Mold Steel La Belle® Silicon #2 Ather Preu

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Crucible research and development continues to match Industry's need for new and improved tool steels. You can profit from the experience gained by Crucible in the application of tool steels to thousands of uses. Our metallurgical service is freely available to you . . . and our conveniently located warehouses maintain a full supply of tool steels for prompt delivery.

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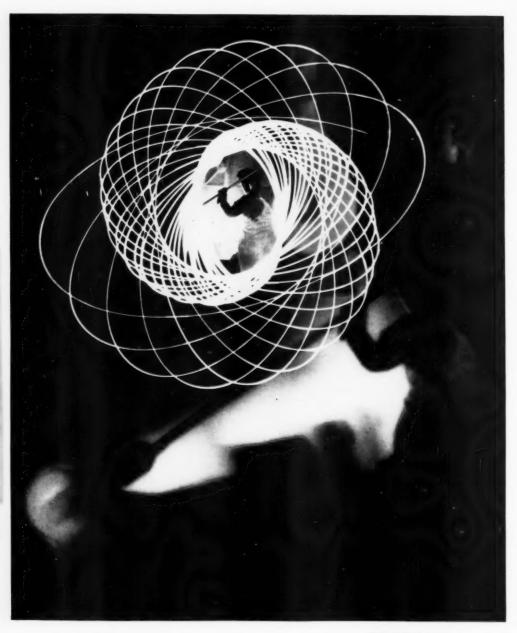
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Because every analysis of Timken forging steel has uniform forgeability, with superior surface and internal quality, you get better and more uniform finished products. Rejects, delays and changes in shop practice are reduced.

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SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING



As a leading supplier of tubing to builders and users of radiant tube furnaces, Pressed Steel Company's assemblies dependably furnish such general features as compactness, removability, uniform heating over tube length, etc. The distinctive feature of PSC radiant furnace tubes is their light-wall construction. Installation records repeatedly show that this feature effects marked economies in fuel and furnace time. Our "light-wall" construction is based on a quarter century's experience in precision fabrication of sheet alloys.

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Tubes for all types of radiant furnaces. We specialize in secondary burner tubes for highest temperatures.

EQUIPMENT IS light-wal ance and

Let us show you how PSC light-wall tubes cut maintenance and furnace time.

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Carburizing and Annealing Boxes Baskets - Trays - Fixtures Muffles - Retorts - Racks Annealing Covers and Tubes Pickling Equipment Tumbling Barrels - Tanks Cyanide and Lead Pots Thermocouple Protection Tubes Radiant Furnace Tubes and Parts Heat, Corrosion Resistant Tubing



We precision assemble the most complicated designs of radiant furnace tubes. Send blue prints or write as to your needs. We fabricate heat-treat units from the complete list of alloys. You can choose the metal that is "alloy-right" for your needs.

## THE PRESSED STEEL COMPANY

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING Sheet Alloys

BELLEVUE INDUSTRIAL FURNA-SURFACE COMBUSTION CORPORATION COLUMN SPENCER EQUIPPED SUNBEAM STEWART FOUNDRY EQUIPMENT COMPANY SIMCE R.S. PRODUCTS, min. P. CORPORATION. HARTFORD EMPIRE COMPANY CLAUD S. GORDON COMPANY 1918 AMERICAN GAS FURNACE COMP 1920 INDUSTRIAL HEATING EQUIPME 1921 YOUNG BROS. COMPANY. 1921 THE ELECTRIC FURNACE CC 1922 STANDARD FUEL ENGIN 1925 1926 GEORGE J. HAGAN C 1928 AMSLER MORTON C 1929 1929 ALLIED ENGINEERIN 1929 THE ANTHONY CC 1930 1930 CONTINENTAL IN 1933 1933 SALEM ENGINEER Thirty five years ago the Spencer Turbo was first specified by a furnace 1934 THE CARL MAYE manufacturer. Since that time, the list 1934 has grown to more than thirty-all of DESPATCH OVEN 1935 whom are Spencer users today. THE DREVER CON The reasons they prefer Spencer are 1935 the absolute reliability - perfect per-NICHOLS ENGINEE formance and low maintenance over 1937 long years of almost continuous service. 1939 Complete information in Bulletin No. 126-A. For other industrial uses, ask for 1940 Turbo Date Book No. 107-C. 1940 35 TO 20,000 C.F.M.: 4 OZ. TO 10 LBS.; 1/3 TO 1,000 H.P.

THE SPENCER TURBINE

APRIL 1952; PAGE 37

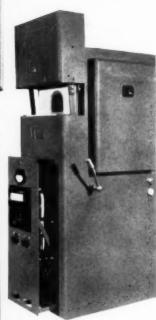
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BURRELL CORPORATION offers

## NEW ELECTRIC FURNACE LINE

...equipped with GLOBAR
Heating Elements





For information on the new Burrell furnaces, address your inquiries to Burrell Corporation, Fifth Ave., Pittsburgh 19, Pa.

These new Burrell furnaces incorporate the best features of previous dual purpose models with additional new features such as the pull-out control panel shown here in opened and closed position.

As a pioneer in the development of laboratory furnaces, Burrell was one of the first to realize the advantages provided through the use of GLOBAR silicon carbide heating elements. The present line of compact Burrell Unit-Package furnaces are simple to operate and give long, trouble-free service. Heating-up time is fast...working temperatures can be changed, up or down, to suit the job. The GLOBAR elements are engineered to size and number to give most efficient service. They can be replaced speedily, from the outside, without cooling the furnace.

Burrell's experience is typical of many other manufacturers who have found that GLOBAR heating elements are excellent for a variety of diverse operations where they provide advantages in furnace design, construction and performance. We will be glad to send you complete data on GLOBAR elements upon request to Dept. MP 87-106, GLOBAR Division, The Carborundum Company, Niagara Falls, New York.

## GLOBAR Heating Elements

Heating Elements by CARBORUNDUM

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## Reduce the use of critical alloys in gas turbine structures

N-A-X AC9115 ALLOY STEEL offers a means of reducing the use of critical alloy steels of the "stainless" type in gas turbine and similar applications. In specific cases it has replaced over half the amount of strategic material originally required, with no sacrifice of quality.

N-A-X AC9115 ALLOY STEEL has high strength and toughness values at temperatures ranging from  $-70^{\circ}$  F. to  $+1,000^{\circ}$  F. It can be readily cold formed into the most difficult shapes; its response to welding by any process is excellent. It must, however, be suitably coated for protection against cold or hot corrosion.

N-A-X AC9115 ALLOY STEEL is available in bars as well as flat rolled products. Investigate the outstanding properties and characteristics of this steel and, through its use, conserve the critical material so necessary to our nation. with N.A.X.
AC9115

**ALLOY STEEL** 

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NATIONAL STEEL CORPO



### "I wonder what happened to me!", said Alice

ALICE in Wonderland ate the magic cake and grew until she was more than nine feet tall. Our National bureaucracy also seems to have partaken of the magic cake of power. Bureaus in our government have grown in number and scope until their activities now control, to a great extent, the lives of all individual Americans. Department after department adds more and more people -- state, justice, commerce, treasury-not to mention those sprawling emergency born agencies of price control, N.P.A. and other alphabetical subdivisions.

The number of employees of our federal, state and local governments continues to grow. During many recent months, personnel was added to the federal payroll at the rate of 1.500 daily.

What is the reason for this mushrooming? The Korean War? Threat of war in Europe, Southeast Asia, or the Middle East? Obviously not! A glance at the federal budget gives the answer. The estimated cost of all governmental functions for the fiscal year 1952 is in excess of 70 billions of dollars, an increase of 26 billions, or approximately 60% more than last year.

When will it end? Only you, the individual citizen, who carries the bureaucratic load on his back, can stop it. It will end when enough patriotic men and women demand from congress that the Washington Wonderland start shrinking back to reasonable proportions.

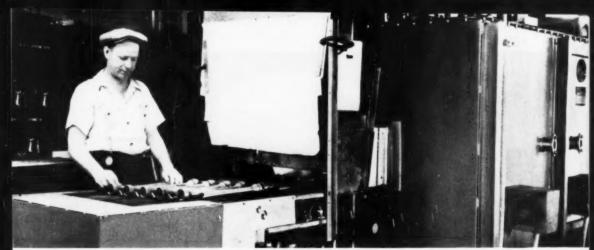


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General Offices -- Youngstown 1, Ohio Export Offices -- 500 Fifth Avenue, New York

MANUFACTURERS OF CARBON ALLOY AND YOLOY STEELS

The steel industry is using all its resources to produce more steel, but it needs your help and needs it now. Turn in your scrap, through your regular sources, at the earliest possible moment.



Use G-E electric brazing furnaces and less-critical stamping, screw-machine and punching facilities to make assemblies that you now make by forging, casting or machining.

## Relieve Forging and Machining Bottlenecks

Time, money, materials saved by G-E electric-furnace brazing



This 1½-ounce breather assembly for fuel-injection pumps was formerly machined from a one pound steel blank. Now a small screw-machine part and a stamping are electric-furnace brazed, reducing cost 70 per cent.



In another plant, rocker-arm assemblies were formerly cast. Now made of seven stamped parts and furnace brazed, machine work has been cut 50 per cent, weight decreased 25 per cent and cost cut 20 per cent.

LEARN MORE about electric furnace brazing for your plant. Call your G-E Sales Office, or send this coupon.



It has been proved that bonds made by electric-furnace brazing have great strength and excellent appearance. This test bar, made of many  $^{1/2}\mathbf{x}^{-1/2}\mathbf{x}^{-1/4}$ -inch steel blocks copper-brazed together, resists shear even when twisted 360 degrees.

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### The Superior Tube That Puts You "On Target"

Hitting specification bull's-eyes to help our customers hit their production targets is a Superior specialty.

A case in point is illustrated above. The customer, W R. Weaver Company manufactures high-quality telescopic sights for sporting and target rifles. The carbon steel tube in which the lens elements, reticule and eye piece are mounted must be strong and rigid. Tube material must have excellent machining qualities to permit fast, economical, precision working. Because salability depends a good bit on fine appearance, the tube must be extremely smooth and free from pits and scratches. This is particularly true of the larger sizes where tube ends are expanded, making imperfections more evident. Inside surface must also be smooth and to accurate dimensions.

Ordinarily you might expect tubing to fit such requirements for smoothness plus temper and machinability would be a "premium" item carrying extra charges for special handling.

Not at Superior. Here we can take the most exacting specifications in stride because of our experience and "knowhow" backed by highly developed production equipment and extensive research and testing facilities.

If you have need for fine, small tubing to do a tough job well, check with us. We can probably fill your requirements from the stocks of our distributors who are located in principal cities. Write Superior Tube Company, 2008 Germantown Ave., Norristown, Pennsylvania.

All analyses .010" to %" O.D. Certain analyses (.035" max. wall) up to 1%" O.D. ROUND AND SHAPED TUBING

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Alloy Steels:

A.J.S.J.—4130, 4132, 4140, 4150, 8630, E-52100

Stainless Steels:

A.I.S.I.—303, 304, 305, 309, 310, 316, 317, 321, 347, 403, 410, 420, 430, 446, T-5

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- Engineers at Arwood Precision Casting Co. use TOCCO Induction Melting Furnaces for melting and remelting quality steel. Other companies have found TOCCO equally adaptable for melting non-ferrous metals. No wonder! Look at the advantages:
- \* Stepless power control
- \* Extremely Rapid Melting
- ★ High Efficiency on Intermittent Operation
- \* Good Mixing because of Natural Agitation
- \* Extremely Low Alloy Loss
- \* No Carbon Pick-up
- ★ No Contamination when Composition of Charges is Changed
- ★ High Reproducibility of Results
- \* Minimum Space Requirements
- \* No Special Installation Charge
- \* Simple, Safe Operation
- \* Clean, Comfortable Working Conditions

If any of these advantages suggest economies in your operations write for full details—no obligation, of course.

THE OHIO CRANKSHAFT COMPANY

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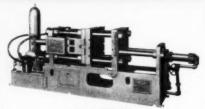
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Company
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City
Zone
State

#### FIRST NAME IN DIE CASTING MACHINES

## NATIONAL REJECTORS, INC.





MODEL HP-20

Hydraulically operated die casting machine for production of aluminum castings.

The desire for a soft drink or a candy bar, . . . a vending machine and a coin. They're the ingredients it takes to make "magic with a nickel!" Right before your eyes, a miracle of miracles takes place. The proper change is returned plus the refreshment . . . all due to a remarkable behind-the-scenes mechanism made by NATIONAL REJECTORS, INC.

Using KUX die casting machines, NATIONAL REJECTORS, INC. turns out thousands upon thousands of intricate, extremely sensitive coin control devices that automatically check the coin for authenticity, return the exact change . . . and please your appetite!

Does YOUR PRODUCT require pin-point accuracy? Quality die castings often provide the difference between success and failure . . . profits and losses. KUX, first name in die casting machines, can make that difference for YOU!

Write for illustrated catalog showing complete line of KUX Die Casting Machines.

KUX MACHINE COMPANY 6725 N. RIDGE • CHICAGO 26, ILLINOIS

FIRST NAME IN DIE CASTING MACHINES SELECTED BY FIRST NAMES IN INDUSTRY



REPUBLIC STEEL CORPORATION

Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N. Y.





Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Belts and Nuts, Tubing

producer of alloy and stainless steels.



Wire Heat Treating Units

Scratchboard Drawing for Pittsburgh Steel Company by T. W. Hunter

### **Progress in Steel**

#### New Oil-Tempering Units Improve Wire Quality

In order to better serve steel users, Pittsburgh Steel Company includes in its Program of Progress the diversification of its line of products.

For example, the two oil-tempering units shown above have been installed to produce high-quality, oil-tempered spring wire. The new product is made by a closely controlled continuous process in which the wire is heated to a predetermined temperature, quenched quickly in a hot oil bath and then "tempered" by passing it through a bath of molten lead. This hardens and toughens the wire, increases its tensile strength—makes it suitable for mechanical springs

such as those used in planes, tanks and jeeps, as well as in automobiles, trucks, diesel locomotives and agricul-

Pittsburgh Steel's policy of expanding its line of products as a part of its Program of Progress has extended into the field of flat rolled products. Last year, the Thomas Steel Company at Warren, Ohio was acquired, thus marking the entry of Pittsburgh Steel into the flat rolled product market. This year a new 66-inch continuous hot strip-sheet mill and a new 66-inch 4-stand, 4-high tandem cold reducing strip-sheet mill will go into operation at the Allenport

Works. Another step in the Program of Progress — the new blooming-slabbing mill at the Monessen Works—has been completed. It is handling the increased flow of ingots coming from the enlarged open-hearth furnaces which this year will produce an extra half-million tons of steel. To help make this possible, blast furnace capacity is being increased by 100,000 tons a year.

The entire Program of Progress at Pittsburgh Steel is an important part of the steel industry's answer to the need for more and better steel to help defend the free world while still supplying reasonable civilian requirements.



## Pittsburgh Steel Company

Pittsburgh, Pennsylvania

# NOW REMOVE RUST FAST WITHOUT ACIDS!

Enthone

## ALKALINE DERUSTING COMPOUND 134

Do You Know What This Means?

- Absolutely no tarnishing, etching or darkening of steel during derusting.
- 2 Clean and derust in one operation.
- 3 Reclaim rusty tools, gears and delicate threaded parts.
- 4 No acid or corrosive fumes around.
- 5 Greater adhesion of chromium, silver and nickel electrodeposits also vitreous enamels.
- 6 Derust high carbon steel, cast and malleable iron and leave a white clean surface.
- 7 Derust coppered, galvanized and tinned surfaces without stripping the copper, zinc or tin, e. g. milk cans.
- 8 Pickle fast at room temperature.
- 9 Clean, derust and deposit zinc or cadmium plate in one operation.

Write for literature on this new discovery and also get the Enthone check list of 60 new research products for metal finishing.

METÁL FINISHING PROCESSES ENTHONE

THE RESERVE OF THE PARTY OF THE

ELECTROPLATING CHEMICALS

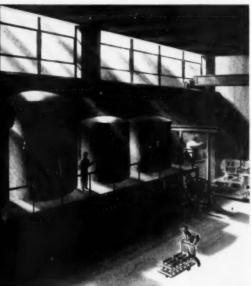


## National Research Corporation

Announces



U. S. A.'s Sole Commercial
Source of Vacuum
Melted Metals



Vacuum Metals Corporation has been formed to supply specialty metals and alloys for applications of high performance in terms of physical, chemical or electrical properties.

Vacuum melting techniques developed by National Research are used to produce metals of higher purity and alloys held to closer composition tolerances than ever before achieved commercially. Organized by National Research as a wholly-owned subsidiary, Vacuum Metals Corporation now has facilities for vacuum melting more than five tons per day of metals such as copper, nickel, molybdenum or iron.

The unique properties of vacuum melted pure metals and alloys are particularly useful in applications such as electronic and electrical parts, magnetic materials, bearing materials, diaphragms, instrument components, laboratory standards and Atomic Energy projects.

Write to us for further information about our facilities.

#### VACUUM METALS CORPORATION

Subsidiary of National Research Corporation

70 MEMORIAL DRIVE . CAMBRIDGE 42, MASSACHUSETTS

HIGH PURITY METALS - HIGH VACUUM CASTING - SPECIAL ALLOYS - GF (Gos Fros) METALS

## Fine steels made to order

No matter what type of special steel you order from Jessop . . . whether it be tool steel or saw steel, stainless clad or flat stock . . . you can buy with confidence knowing that it has not been picked from warehouse stock. Fine Jessop steels are tailored to your specific need. There's another thing you can be sure about when you order from Jessop. You'll get good service. Youthful, revitalized Jessop wants your business. The entire organization will work hard to bring you the degree of satisfaction that will make you a permanent customer.

HIGH SPIED STEELS - HIGH SPIED BITS - PRECESOR GROWN FLAT STOCK - HIGH SPEED AND ALLOY SAW STEELS - HOT WORK DIE STIELS - COLD WORK DIE STEELS - CARROW AND ALLOY STEELS - STAINLESS AND NEAT RESISTING STEELS VALVE STEELS - STAINLESS CLAD STEELS - CAST-TO-SMAPE STEELS - COMPOSITE TOOL STEELS - ARMOR PLATE

**IESSOP** 

STEEL COMPANY WASHINGTON PENNSYLVANIA

## 50th Anniversary

1902

1952

## DESPATCH OVEN COMPANY

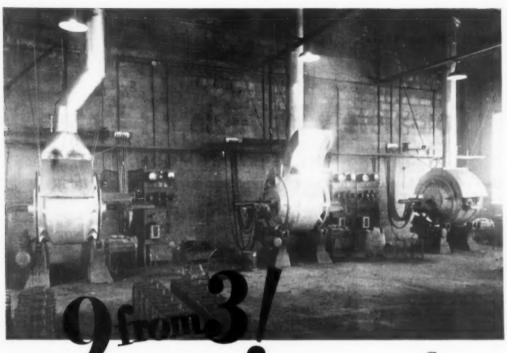
Pioneers in engineering heat applications for industry

#### DESPATCH OVEN COMPANY

MINNEAPOLIS OFFICE:

CHICAGO OFFICE:

SALES OFFICES IN ALL PRINCIPAL CITIES



## NINE TONS OF HIGH QUALITY IRON PER SHIFT FROM THESE 3 DETROIT ROCKING ELECTRIC FURNACES

Vassar Electroloy Products Company has based its growth on precisely controlled, quality iron and steel castings. In five years, metal melting requirements have increased more than 700%.

Today, three 700-lb. Detroit Rocking Electric Furnaces keep the pouring ladles full, producing alloys with exact metallurgical and physical characteristics melt after melt. The fast, efficient operation of these furnaces maintains high production levels and high standards of economy.

For melting ferrous or non-ferrous metals, these indirect arc furnaces have many advantages; easy, positive control; uniformity of melts; thorough mixture of elements through the melts; optimum use of power; less metal shrinkage; more heats per day; easy shell replacement.

Furnaces are available in 10 to 4,000 lbs. capacity, designed specifically to fit your electrical specifications. Get full information. Write today!



AT ATLANTIC CITY

See this Detroit furnace in operation at our booth at the Foundry Show. It will be melting alloy iron used in an interesting shell molding demonstration by The Borden Co.

#### DETROIT ELECTRIC FURNACE DIVISION

KUHLMAN ELECTRIC COMPANY, BAY CITY, MICHIGAN

Foreign Representatives: in BRAZIL—Equipamentos Industrios, "Elsa" Ltd., Soo Poulo, CHILE, ARGENTINA, PERU and VENEZUELA: M. Castelivi Inc., 150 Broad-ey, New York 7, N. Y., MEXICO. Ciz Provedors de Industrios, Atenas 32-13, Apardado 27A3, Mexico 6, D. F., Mexico, EUROPE, ENGLAND: Birliec, Itd., Birmingham





Use it Anywhere...
in the laboratory...
oil field...orchard...mine...
mill...food plant...

Anywhere!

## **Completely Portable pH Meter**

THE BECKMAN MODEL N

#### Check over these features:

- . Accuracy to better than 0.05 pH.
- Low operating cost—loss than 2¢ per hour.
- Built-in temperature compensation—
  Of to 100° C.
- · Fast warm-up of less than 10 seconds.
- "Check pointer" eliminates need for frequent buffer standardization.
- Batteries are easily checked with the regular penal controls. No need to disassemble the instrument. Clip-mounting of batteries eliminates need for soldering or wiring.
- All-metal case of cast aluminum with baked engmel finish to resist wear and corresion.
- Splash-proof design, fully desiccated internally.
- Shock-proof. Each tube is individually shock-
- . Weighs less than 8 lbs., complete.
- Equipped with the new Beckman Red Label Glass Electrode—virtually unbreakable, cavers almost the entire pH range, usable from freezing to boiling.
- By for the most rugged everall construction of any pH motor.



The new Beckman Model N pH Meter is entirely independent of any outside power circuit. It meets perfectly the wide demand for a completely portable battery operated pH instrument that is inexpensive, light in weight, compact, and rugged enough to be used anywhere. The newly developed Beckman Model N not only meets all these requirements, but many more. For instance, the electrode support rotates alongside the case for maximum convenience in carrying. Instrument can be used in either horizontal or vertical position. Convenient controls not only centralize all operating functions, but also permit checking amplifier circuits and battery condition without opening case or disturbing battery connections

#### Two Models are Available:

- Model N-1 (illustrated), without a cover but with a rigid handle—12 inches long, 4½ inches deep, 7½ inches wide including electrodes. Complete with glass and reference electrodes, electrode holder, 50 ml beaker, buffer solution, 100 ml KCL solution, 100 grams KCL crystals.
- 2. Model N-2 (not illustrated), with a cover-compartment hinged to the case with spaces for 2-ounce bottles of buffer solution and distilled water, thermometer, electrodes and beaker—12 inches long, 8 inches deep, 7½ inches wide including electrodes. Complete with the same accessories as listed above for Model N-1 and in addition, thermometer 0-100°C, polyethylene bottles for buffer solution and distilled water.

H-29601-Beckman Model N-1 pH Meter.

Each . . . . . . . . . . . . \$180.00

H-29602—Beckman Model N-2 pH Meter. Each . . . . . . . . . . . . . . . \$195.00

(Quantity prices on request)

For further information on these instruments or any other Beckman product, contact the Harshaw Scientific office nearest you.

HARSHAW SCIENTIFIC
DIVISION OF THE HARSHAW CHEMICAL CO.
CLEVELAND 6, ONIO

Cleveland 6, Ohio 1945 East 97th St. Cincinnati 2, Ohio 224-226 Main St. Detroit 28, Mich. 9240 Hubbell Ave.



Houston 11, Texas 6622 Supply Row Los Angeles 17, Calif. 3237 S. Garfield Ave. Philadelphia 48, Pa. Jackson & Swanson Sts.



The famous Hamilton Beach name is a well-respected guarantee of quality in consumer markets. As with other successful manufacturers, quality in terms of de-

sign, materials and production is of utmost importance. Silvaloy Brazing experts are successfully helping to improve results, increase production and lower costs for many thousands of manufacturers. We would like to have you make all possible use of this valuable technical service—without obligation. Call or write. A Silvaloy technician will visit your plant at your convenience.

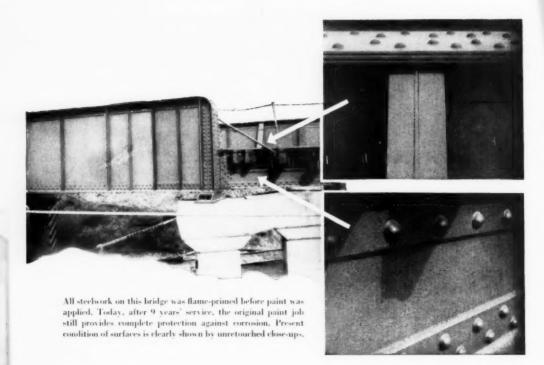
> SILVALOY SILVER BRAZING ALLOYS ARE SUPPLIED FROM STOCK THROUGH A RELIABLE DISTRIBUTOR IN YOUR AREA.

SEND FOR THIS 48-PAGE "COMPLETE GUIDE TO SUCCESSFUL SILVER BRAZING!"

231 NEW JERSEY RAILROAD AVENUE, NEWARK 5, NEW JERSEY

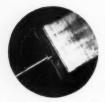






#### Your Steelwork . . .

### How Will It Look in 1960?



Steelwork you coat with good paint today can still look like new ten years from now, if you flame-prime all exposed surfaces first. And what you'll save on main-

tenance, because of increased protection due to flame-priming, will more than pay for all the flamepriming apparatus and materials you need for the job.

Flame-priming is simple to do, requires little equipment, and costs little. A brush of oxy-acety lene flames pops off scale and drives out moisture. Paint applied to the warm, dry surface goes on quickly and smoothly, bonds tightly, and lasts longer.

Flame-priming is one of many time- and moneysaving LINDE methods for making, cutting, joining, treating, and forming metals. So, whatever you do with metals, there is a good chance that LINDE know-how, show-how, and equipment can help you do it better, more quickly, or at lower cost.

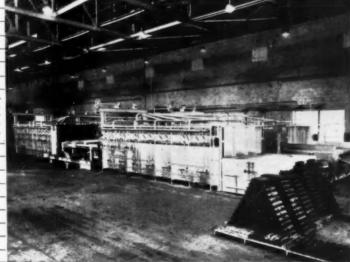
To find out, without obligation, telephone or write our nearest office today. LINDE AIR PRODUCTS COMPANY, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. Offices in Other Principal Cities. In Canada: Dominion Oxygen Company, Limited, Toronto.



Products and Processes for MAKING, CUTTING, JOINING, TREATING, AND FORMING METALS

The term "Linde" is a registered trade-mark of Union Carbide and Carbon Corporation.

Loftus beat treat line for treating shell cases provides completely automatic operation from loading conveyor to unloading conveyor.



## They Specify Life for Outstanding Performance!



Production rate increases of 50% have been achieved through installation of this Loftus strand furnace,

Liftus automatic continuous furnace for forging and heating produces look, easily removed scale.





Loftus customers' experience has proven the superior performance, greater efficiency, and faster production rates achieved with Loftus heat treating furnaces. Loftus offers exclusive features such as "Pin-Point Quench" which assures absolutely accurate quench temperature. The Loftus "COVERALL" contract includes design, construction, installation, and operation.

Send today for 16 page Booklet:
"Proven Heat-Treating Efficiency by Loftus." Shows many Furnace Types,



610 Smithfield Street, Pittsburgh 22, Pennsylvania





The rust-proofing of iron and steel products is a "sacrificial" function of metallic zinc which for many years has accounted for the metal's largest single use. Nearly 50% of all the zinc consumed in the United States is used for galvanizing. This "sacrificial" characteristic of zinc in providing iron and steel with low-cost protection against rust is also responsible for the increasing use of the metal in the form of anodes for the cathodic protection of underground pipe lines. The property of zinc which makes this possible is due to its advantageous position in the electromotive series. As indicated by the listing on the right, of the commonly available metals which are electronegative to iron, zinc stands far enough below iron so that its electronegative potential provides effective and economical cathodic protection, but not so far as to sacrifice itself needlessly and beyond the immediate duty for which it was designed: To mitigate the insidious electrochemical action of nature known as corrosion, by providing efficient cathodic protection to the millions of miles of our nation's underground pipe lines.

#### ST. JOSEPH LEAD COMPANY

250 PARK AVENUE, NEW YORK 17, N. Y. ST. JOE Electro-Thermic ZINC: High grade, Intermediate, Brass special, Prime western BUNKER HILL 99.99+% ZINC

	of the COMMON	METALS*
Vs. H2		Vs. Iron
+1.36	Gold	+1.80
+0.86	Platinum	+1.30
+0.798	Silver	+1.23
+0.344	Copper	+0.78
0.000	HYDROGEN	+0.44
-0.12	Lead	+0.32
-0.14	Tin	+0.30
-0.23	Nickel	+0.21
-0.40	Cadmium	+0.04
-0.44	IRON	0.000
-0.56	Chromium	-0.12
-0.762	Zinc	-0.32
-1.33	Aluminum	-0.89
-1.55	Magnesium	-1.11

• U. R. Esans, "Metallic Corrosion, Passissity & Protection", Rusting is an electrochemical action in which tron replaces hydrogen, or a metal, in an electrolyne. Each metal has its own definite activity in this respect, which is termed is electro-potential. A list of the metals arranged in increasing electro-potential. A list of the metals arranged in increasing volts is called the Electromotive Series. For convenience—at the right hand side of the above table—the zero point has been placed at iron and the figures, since they are relative only, have been transposed to show the metals' activity relative to iron.



I. Tin, electro-positive to iron, has no protective action.



II & IIa. Zinc, electro-negative to iron, with a driving voltage of 0.5 volt more than iron in soil or water, provides efficient protective action through sacrificial corrosion.



for Galvanic Protection Zinc is Standard



## NEW! Johnson's STIK-WAX

An entirely new kind of lubricant that outperforms grease sticks, tallow, bar soaps!



On grinders
Stik-Wax lubricates to reduce heat—wheel clogging.

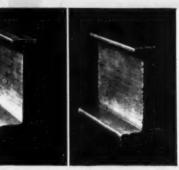
On belt sanders Stik-Wax lubricates to give better finish longer belt life.



On taps
Stik-Wax lubricates
to cut smoother
threads — increase
life of taps.

On band
or circle saws
Stik-Wax lubricates
to lengthen blade life
—gives smoother cuts
—reduces burns.





Sawed sections of aluminum extrusion. Left: section sawed with Johnson's No. 140 Stik-Wax is burrfree. Right: section sawed with grease stick shows bad burr.

Johnson's No. 140 Stik-Wax is the new wax lubricant that outperforms grease sticks, tallow, bar soaps. Saves materials and tools . . . saves time . . . produces higher quality work.

Exhaustive tests have shown that the performance of Johnson's No. 140 Stik-Wax far exceeds that of ordinary lubricants for drilling, grinding, sawing, tapping, spinning and pipe cutting. Taps and drills last far longer. Saws and cutters need sharpening much less frequently. Sanding belts and disks get added life... give cleaner, smoother finishes.

Applied manually or automatically, there is no end to the metal working lubricating jobs that Stik-Wax will do bester to speed jobs . . . add life to equipment.



Test STIK-WAX in your plantIndustrial Products Dept. MP-4 S. C. Johnson & Son, Inc. Racine, Wisconsin

Please send free sample of Stik-Wax for testing . . . also send complete information and instructions for use.

ame Title

Organization.

Addres

Manufacturers

LOOK FOR THIS SIGN

on the profit road...



Your profit for tomorrow will be decided by the work you produce today.

Keep every production line running with fewer breakdowns and less replacements by using ACCOLOY Heat and Corrosion Resistant castings.

The improved designs, finer grain size, the close control of pouring and the multiple testing of each finished piece, all contribute to the longer service life of these castings.

As a manufacturer using trays and fixtures, carburizing boxes, salt pots, retorts, muffles or roller rails — make an investment now that will keep you posted on the profit side of the ledger.



#### ALLOY ENGINEERING & CASTING COMPANY

ALLOY CASTING CO. (Div.)
CHAMPAIGN • ILLINOIS

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

## Park Chemical Company BY THE Research Laboratory OF THE PARK CHEMICAL CO.

## Tests Show New Quench Oil has Intensified Triple Action

PARK'S Triple A Quench Oil has intensified triple action:

1. Rapid heat removal with faster cooling rate in the critical range giving higher and deeper hardness. 2. Slow cooling through the hardening range, minimizing distortion.

3. Great stability due to special anti-oxidants. Result is longer life and bright quenching properties.

An explanation of the quenching process illustrates how Park Chemical Company with over forty years of chemical and metallurgical background developed an ideal oil to fit the ever mounting production quenching problems.

Three stages of cooling are observed when steel is quenched in oil from a red heat. (A) Formation of a vapor film at the steel surface; cooling is accomplished by conduction and radiation through this vapor film and is relatively slow. (B) Direct contact of the oil with the metal surfaces causing a boiling action which continually dissipates the vapor film formed and results in rapid cooling. (C) After the metal has been cooled to the boiling point of oil, vapor is no longer formed; cooling is by conduction and convection, and the metal slowly cools to the temperature of the oil.

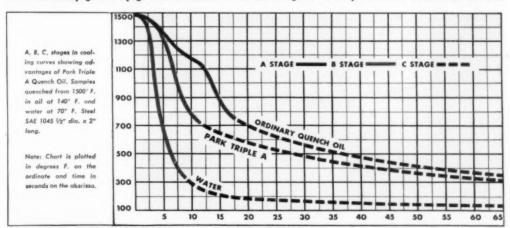
Although water and water solutions provide high cooling rates throughout these three stages of quenching, they are

often impractical because rapid cooling is not desirable in the lower ranges of temperature where martensite is formed. It is at this time that temperature differentials within a piece of steel cause warping and cracking. Thus oil quenching is preferred for all steels possessing sufficient hardenability to avoid transformation to soft structures in stages A and B, since the cooling rates furnished by oils during Stage C are ideal for preventing temperature differentials.

It is apparent that any improvement in the cooling power of oil in Stages A and B would be most desirable. Such improvement is obtained in water quenching by the addition of salt or caustic soda. The brine or caustic solution has a wetting action which completes the quenching job faster than fresh water. Fresh water takes hold only in spots causing non-uniformity. Brine solutions provide deeper and more uniform hardnesses. It seems logical to attempt to do this same thing with oil. The mineral intensifiers added to Park's Triple A Quenching Oil act in this manner.

The accompanying cooling curves serve to illustrate how this additive has altered the quenching power of the oil in the A and B stage, yet has retained the desirable slow cooling in the C stage.

This is the front page of a 4 page Technical Bulletin on Oil Quenching. For the complete bulletin write for Bulletin F-8.



PARK CHEMICAL COMPANY, 8074 MILITARY, DETROIT 4, MICH.







## HAS PRODUCTION ON YOUR METAL WORKING JOB GOT YOU UP IN THE AIR?\*

You're on solid ground when you depend on Brandt's flexible mass production facilities . . .

# BRANDT

Despite stepped-up defense contracts, industrial accounts still receive prime consideration. Time-wise contractors on completely assembled components place their orders with Brandt and forget them!

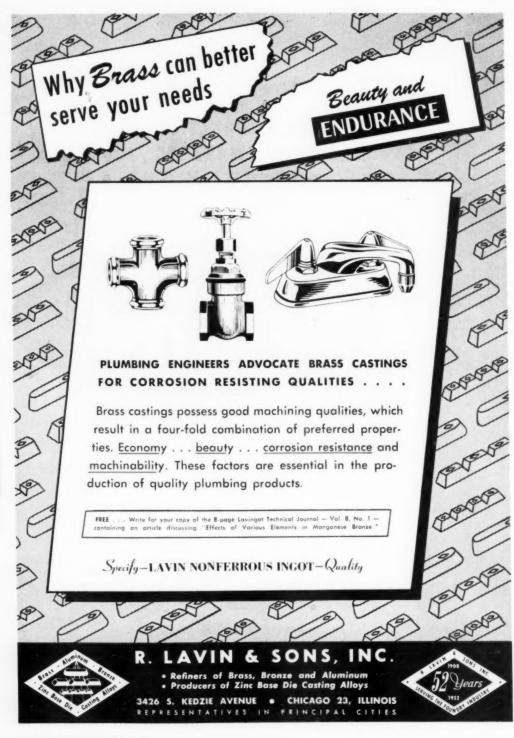
STAMPINGS • WELDMENTS

SPOT WELDED ASSEMBLIES • PRESSED STEEL SHAPES
in all types of metal

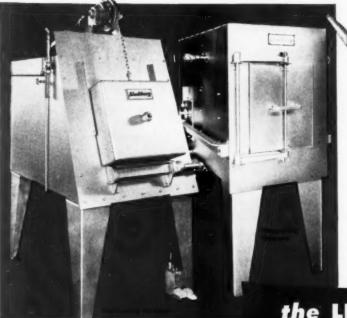
\* Send for handy file folder of complete facilities.



of modern, mass production close to main line rail, highway and air transport.







BASIC **FOR EVERY TOOLROOM** 

the LINDBERG **TOOLROOM TEAM** 

When production depends on tools and dies, tools and dies depend on the LINDBERG TOOLROOM TEAM-a basic requirement in every toolroom-a must where you want the ultimate in tools and dies which will keep your production rate up and your machinery running with a minimum of tool and die failure. The LINDBERG TOOLROOM TEAM gives you the precision heat treating which your precision tools and dies need for lasting performance.

LINDBERG HARDENING FURNACEeliminates finishing due to scale and decarb with simple accurate atmosphere control.

LINDBERG TEMPERING FURNACEallows you to obtain the exact "Rockwell Hardness" required for each specific tool or die.

For tools and dies requiring high speed tool steel-investigate the Lindberg "L" Type combination preheat-high heat Furnace.

LINDBERG FURNACES



LINDBERG ENGINEERING COMPANY W. Hubbard Street, Chicago 12, Illinois





# This heat-treating record ...is **NEWS**

The above chart shows a record of surface carbon control during four types of heat-treating processes. During three of these operations carbon is added; during the fourth, it is accurately maintained.

This record, provided by the familiar Micromax Recorder modified for this purpose, is an exclusive feature of the Microcarb method of carbon control as applied to the Homocarb furnace. There is no other way of getting even one of these records, much less all four.

Ninety-nine out of a hundred metallurgists and heat-treaters will find this record is new... something they have never seen before. It tells them exactly what's going on... gives the heat-treater time enough to modify the process or take whatever other action is desirable. It's the NEW way to reduce rejects.

The significance of this new development will, of course, depend upon the plant setup, and must be assessed individually by the metallurgist or heat-treater concerned. However, initial users of Homocarb with Microcarb control are enthusiastic.

One such firm found the results so important to their customers that they featured the story in their own advertising. As more and more manufacturers become familiar with the advantages of Homocarb plus Microcarb, this equipment will soon be more generally known to men who look for the modern way to carburize.

Let us send you further facts about this new development. We may be contacted at our nearest office, or 4927 Stenton Ave., Phila. 44, Penna.

LEEDS & NORTHRUP C

Ic. Ad TD4-623(7)

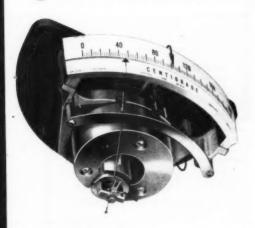
INSTRUMENTS

AUTOMATIC CONTROL

FURNACES



# G-E pyrometer equipment resists vibration; gives accurate, uniform temperature control



RUGGED AND ACCURATE. Indicator unit has 3½ lb. alnico magnet and stationary parts, plus lightweight moving system—a combination that can withstand great stresses. In the installation shown above, the pyrometer units are giving close temperature control even though subjected to constant vibration, transmitted through frame supports. The atmosphere is filled with coal dust, and has a high ambient temperature. Yet "there has been no trouble in 14 months of operation." So writes a prominent eastern manufacturer.

STURDY CONSTRUCTION throughout makes the General Electric Type HP-3 pyrometer equipment rugged and vibration resistant. A 3<sup>14</sup> pound alnico magnet provides high flux density, hence a large air gup for the lightweight (1 gram) moving system. This permits reliable operation under vibration.

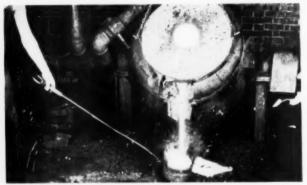
ACCURATE INDICATION and uniform temperature control are assured. Calibrated accuracy is within  $^34$  of 1 per cent of full scale. Automatic cold-junction compensation adjusts for changes in ambient. Normal changes in humidity and voltage have little or no effect on the stability of control.

MORE INFORMATION can be obtained from your G-E representative, or write for Bulletin GEC-713. General Electric also offers a complete line of thermocouples—described in GEC-714. Write Section 602-231. General Electric Company, Schenectady 5. New York.

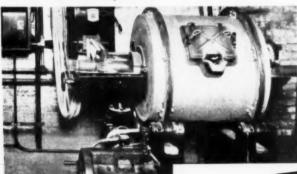
GENERAL 8 ELECTRIC



THIS REVERBERATORY FURNACE is lined with a Norton CRYSTOLON\* refractory cement, engineered to last longer on this particular metal-melting job.



THIS TILTING CRUCIBLE FURNACE has a cover and lining made of a Norton CRYSTOLON refractory cement, It was engineered to fit this firm's individual requirements.



THIS INDIRECT ARC FURNACE owes much of its high output to its lining, made of a custom-engineered Norton ALUNDUM\*refractory cement.

### Melt more metal per furnace-hour

with refractory linings engineered for you

Every time you interrupt your metalmelting campaigns to patch or replace your furnace linings, you lose production you never get back.

That's why just any refractory cement won't do. You want the one cement that fits your requirements so exactly that it reduces interruptions to a minimum. Chances are, the one just-right cement hasn't been made yet.

That's where your nearby Norton refractories engineer enters your picture. He's ready to call on Norton Research... pioneers for 40 years in the development of special refractories for complicated high-temperature requirements.

Working together, you and Norton Company are sure to arrive at the one CRYSTOLON, ALUNDUM, MAGNORITE\* or FUSED STABILIZED ZIRCONIA refractory cement that fits your exact requirements.

For more information about this special Norton service, call your nearby Norton refractories engineer, or write Norton Company, 321 New Bond Street, Worcester 6, Mass. Canadian Representative: A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.

"Trade-Marks keg, U.S. Patent Office and Foreign Countries

NORTON

Special REFRACTORIES

Making better products to make other products better

NORTON COMPANY, WORCESTER 6, MASSACHUSETTS

# Metal Progress

Vol. 61, No. 4 - April 1952

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This month's cover design, representing various types of wire fencing and mesh, is by Roland Jelarcie. Unfortunately credit was given to Mr. Jelarcie for last month's

very handsome cover, representing a dipper-load of iron ore, whereas it is actually the work of Edwin Axel, currently a student at the Cleveland Institute of Art.

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## By John C. Redmond, Vice-President, and John W. Graham, Research Engineer Kennametal, Inc., Latrobe, Pa.

THE CONTINUOUS progress of industrial technology has created a demand for new materials of unusual physical properties. Cemented tungsten carbide is one such material that has been engineered into many industries where high hardness and resistance to wear are required. Its development still continues, and new fields of application are opened every day. It is not generally realized, however, that cemented carbides are a large class of materials based on compounds of carbon and metals other than tungsten that greatly extend the range of properties offered. New compositions are now becoming available which further enlarge their importance.

A new group of cemented carbides based on titanium has been available for service testing for more than three years. They were developed by Kennametal, Inc., and are sold under the trade name Kentanium.

Extensive tests have shown that while the titanium carbides are basically similar to tungsten carbide in such properties as high modulus of elasticity, hardness and resistance to wear, low thermal expansion, and many other characteristics, they possess additional properties which greatly extend the traditional fields of carbide applications. Their resistance to oxidation combined with high strength gives promise for service at temperatures far above the range where "superalloys" are now used. Their low density is a further advantage at high temperature and also in many applications at ordinary temperatures where weight is a factor. These advantages are obtained with a minimum of so-called strategic elements. These new carbides will replace present materials in many applications and can be built into equipment and processes operating under conditions heretofore considered impossible.

Accompanying developments in fabrication techniques permit the manufacture of larger and more complex pieces to close tolerances and in large volume. These methods will be discussed later.

Kentanium is made by procedures similar to those used for "Kennametal" (tungsten carbide compositions). Its principal ingredient is pure titanium carbide. Cobalt was the first auxiliary metal used but it has

since been found that nickel is superior. Iron is sometimes useful. Small percentages of columbium, with or without tantalum as a pure carbide, are also added. The ingredients are ball milled together to very fine particle size, pressed as near to the desired shape as possible, given further shaping as required with or without pre-sintering, and then sintered out of contact with air. During the latter step a large but controllable shrinkage occurs.

# Field of Cemented Carbides Expanded by Titanium Compositions

The general properties are compared with tungsten carbide and superalloys in Table I. For purposes of this table, the grades with 10 to 30% nickel as the auxiliary metal have been grouped together.

The low density of titanium carbide in comparison with the superalloys is immediately apparent. In rotating parts the centrifugal stresses are in proportion to the material's density; thus the stress from this component on Kentanium would be about two thirds that developed on the superalloys.

Hardness is high, thereby indicating good wear resistance. Certain applications to be described later indicate that a large amount of the hardness is retained at high temperature. Likewise, compressive strength is high and remains high in a great degree at temperatures where refractory alloys deform plastically.

Young's modulus approaches that of cemented tungsten carbide and is about double that of ferrous alloys and superalloys. This of course means approximately half the elastic movement developed on alloys for a given stress.

Electrical resistance is intermediate between conductors and resistors. The re-

#### Properties of Titanium Carbide

sistance increases with temperature, corresponding to changes in metallic thermal conductivity, thereby indicating that the material has definite metallic characteristics.

Thermal conductivity of titanium carbide is superior to that of the superalloys. This, together with low thermal expansion, accounts for the superior performance of titanium carbide over high-strength refractory oxides in the many thermal shock tests which have been made.

Thermal expansion of titanium carbide is a straight-line function of temperature. This is related to the stable phases characteristic of the material at 1800° F. and above. Heat treating is unnecessary, and the strength at high temperatures is an inherent property of the titanium carbide phase.

Kentanium retains more of its tensile strength as temperature is increased than do most of the refractory alloys. In laboratory tests, it was found that f the TiC compositions was superior to a

one of the TiC compositions was superior to a well-known refractory alloy above 800° F., on the basis of tensile strength – weight ratios. Tensile tests, however, do not provide a conclusive comparison, especially when

Tensite tests, however, do not provide a conclusive comparison, especially when the carbide must undergo a high tensile stress for a long period of time at high temperatures. A more significant method is the stress-rupture test, which relates the variables of temperature, tensile stress, and time of failure. Figure 1 shows several stress-rupture curves for grades K151A and K152B at various temperatures, as well as for Inconel "X" (which exhibits some of the best properties obtainable in alloys). Several conclusions can be drawn from this chart.

First, it is obvious that cemented titanium carbide is like metal in that resistance to steady stress decreases with increasing temperature. Most of the commercially available heat resistant alloys contain unstable phases above 1500 or 1600° F., and this usually results in a great loss of strength at these temperatures. Evidence shows that the Kentanium materials retain a great proportion of their inherent strength at a temperature several hundred degrees above the range where metallic alloys operate satisfactorily. Fig-

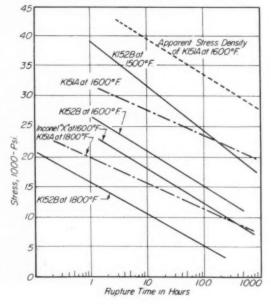
ure 1 shows that K152B has about 125% and K151A has about 170% the stress-rupture strength of Inconel "X" at 1600° F. If time is taken into consideration, it can be seen that K151A would last more than 100 times as long as Inconel "X" at 1600° F, and equal stress.

Another factor particularly applicable to rotating parts is the apparent stress-density advantage. As shown earlier, a Kentanium part would develop about two thirds the stress of an alloy part of the same size and shape rotating at the same speed. This would increase the apparent stress-rupture advantage of Kentanium K151A over Inconel "X" about 44% at 1600° F. The upper dashed line in Fig. 1 shows this relationship. It is figured on the basis that the apparent centrifugal stress in a rotating part is proportional to the density of the material. In the figure, apparent stress equals the actual stress in K151A multiplied by the ratio of densities, Inconel "X" to K151A.

All other factors being equal, a rotating K151A part should last about 10,000 times as long as an Inconel "X" part at 1600° F. Later stress-rupture tests on K151A indicated that its strength and life advantages over Inconel "X" and other alloys are even greater than this.

Work now under way indicates that hightemperature stress-rupture strengths of newer

Fig. 1 — Stress-Rupture Curves for Kentanium, Grades K151A and K152B, as Compared to Inconel "X"



Fabrication of Shapes

compositions may possibly be doubled over the strengths reported here. It also appears that compositions can be produced containing no strategic metals and with stress-torupture properties equaling those of the currently used superalloys which are high in strategic elements. Oxidation resistance would probably be adequate.

Oxidation resistance of the commercially produced compositions is adjusted to the requirements of the application. Those grades having the best oxidation resistance form a tenacious and impervious oxide coating in a short time. Small additions of a complex carbide containing columbium, tantalum and titanium reduce the oxidation to a decreasing parabolic rate.

Oxidation resistance of various grades in air at 1800° F. for 118 hr. are as follows:

GRADE	OXIDATION	
K 138	0.0077 in.	
K138A	0.00095	
K151A	0.00085	
K 159 B	0.00115	

These figures represent the increase in thickness of a thin specimen due to oxide growth on one surface upon heating in an unsealed electric furnace. Improvement of the last three is due to the presence of small amounts of a complex carbide of columbium, tantalum and titanium.

The ductility of the titanium carbide compositions that have been tested is low. The stress-rupture elongation at  $1600^{\circ}$  F. has seldom been over 2% and is slightly greater at higher temperatures.

Improved powder metallurgy and sintering techniques have been developed. As mentioned previously, pure carbide and metal powders are ball milled together under closely controlled conditions. The milled powders are pressed into blocks or ingots having uniform density. The ingots are pre-sintered to the consistency of chalk and. though friable, have enough strength for handling and machining. Large symmetrical round shapes can be turned in a lathe with diamond-tipped tools. Complex shapes such as the turbine impeller shown in Fig. 2 are machined with abrasive wheels by means of usual methods and setups with minor modifications. Milling cutters are usually replaced by high-speed abrasive wheels. Turbine blades and nozzle vanes are machined in large lots on multiple-head automatic machines.

After such machining to shape, the pieces are sintered at high temperatures; allowable shrinkage usually brings the pieces to within 1% or closer to size. If necessary, final design tolerances to within 0.0001 in. can be met by grinding, using diamond and silicon carbide abrasive wheels on standard tool grinding machines. Other fin-

Table I - Comparative Physical Properties of Cemented Carbides

PROPERTY	TiC (a)	WC(b)	Superalloys (c)
General	Properties at	Room Temper	ature
Density, g. per cc.	5.5 to 6.5	11.90 to 15.10	8.3 to 8.7
Hardness, Rockwell A	83 to 93	85 to 93	61 to 65
Modulus of elasticity	55×106 (d)	61 to 90 × 106	$30 \times 10^{6} (d)$
Compressive strength	550,000 psi.	518,000 to	
Conductivity		800,000 psi.	
Electrical (e)	1.9 to 5	4.3 to 9.4	1.37 to 1.8
Thermal (f)	0.075 to 0.085	0.068 to 0.207	0.035 to 0.065
Prop	erties at Eleva	ted Temperatu	re
Thermal expansion (g)	4.5 to 5.0	2.5 to 4	6.73 to 8.5
Oxidation resistance			
at 1800° F.	Excellent	Poor	Good
Tensile Strength			
at 70° F.	80,000 to		
	100,000 (h)	Note (i)	110,000 to 180,000 (j.
at 1500°	55,000		52,000 to 73,000
$1600^{\circ}$	47,000		34,000 to 51,000
1800°	40,000		9,000 to 25,500
2000°	30,000		13,100
2200°	12,500		
2400°	3,000		

#### Notes

- (a) Trade name "Kentanium"; composite properties of grades using 10 to 30% nickel as the auxiliary binding metal, grades K150A, K151, K151A, K151B, K152 and K152B.
- (b) Tradename "Kennametal".
- (c) Range for several Co-Cr-Ni and high-Ni alloys.
- (d) Representative values.
- (e) Percentage of copper standard.
- (f) Calories per cm. per sec. per °C.
- (g) Inches/in./°F.  $\times$  10<sup>-6</sup> at 1200° F.
- (h) Not yet fully established.
- (i) No tests are available.
- Metal Progress data sheet, November 1951, p. 80-B.

#### Wide Range of Applications

ishing methods are being developed. Many complex shapes can be made to such accuracy that no final grinding is required.

Our company has also improved an extrusion technique which produces both titanium carbide and tungsten carbide shapes such as tubes, rods, bars, flats and even objects having complex geometrical cross section.

These manufacturing techniques lend themselves handily to economical volume production of shapes formerly believed too complex to manufacture. Scrap losses from these processes are negligible and material recovery is high.

The properties of Kentanium have been unfamiliar to most metals engineers. In spite of this, various compositions are being introduced into a wide variety of applications. Two of the most promising and perhaps most important are turbine blades and nozzle vanes for jet engines. Another important potential use is in the aircraft industry for valves in high-powered reciprocating engines.

One of the first applications was in spinning tools for hot metal where high strength, wear resistance and good oxidation resistance are requisite. The material is also suitable for tools for trimming flash from hot forgings or pressings.

Small-diameter Kentanium balls having the above characteristics plus a high com-

Fig. 2 — Titanium Carbide Turbine Impeller Designed to Operate at Inlet Temperature of 2000° F.



8 9 10 11 12 13 13

pressive strength are ideal for hot hardness testers. Other high-temperature test machines use cemented titanium carbide as compression dilatometer heads, tensile test heads, pressure sleeves, and anvils for high-temperature transverse rupture tests. Development work is now in progress on hot forging dies used in the forming of refractory alloys.

An example of another severe applica-



Fig. 3 — High-Temperature Pressure Vessel 18 In. Long Withstands 30,000 Psi, at 2300° F.

tion is a pressure reaction vessel shown in Fig. 3 which has repeatedly withstood internal pressures of 30,000 psi, at 2300° F.

A successful room-temperature application is for gage rings that are ground to close tolerances which must be maintained over long periods against abrasion and other material abuses. This is an instance where low density combined with wear resistance is highly advantageous.

Another application in which hightemperature properties are not involved is balls for oil well pump valves. In addition to wear resistance and light weight, resistance to severe corrosion is often required. Promising field results have already been obtained.

Proper design is as essential in the use of cemented titanium carbide as with any other new material. The high modulus of elasticity and the accompanying low ductility usually require changes in design to replace more ductile materials. Titanium carbide can be brazed when required, but mechanical joints are preferred. Radii in highly stressed parts must be as large as possible. Where severe thermal shock is involved, section thicknesses must be as uniform as possible. Other properties must be taken into account in specific design problems.

Thus, there is ample evidence that titanium carbides greatly extend the range of usefulness of cemented carbides and enlarge the possibilities for engineering design.

#### By Marold J. Roast, Foundry Consultant, London, Ont.; Consulting Editor for Metal Progress

NEW SHELL MOLDING process has recently A attracted much attention from American foundrymen, so that the general scheme is fairly well known. Briefly, warm metal pattern plates or core boxes are utilized. A fine granular mixture of sand with a little thermoplastic is poured into the mold box; the resinous binder softens and the mass seeks the contour of the pattern; within seconds a thin, putty-like layer is formed and the superabundant mixture can be dumped. The pattern plate is then heated about 1 min. at 600° F., whereupon the cured (hardened) investment can be lifted off by suitable means. Half molds (with hollow cores) made in this way and containing necessary gates and risers are then bolted together, embedded in metal shot, and poured. The investment (sand plus resin) is destroyed during shake-out, but the metal shot is reclaimed for reuse.

Interest in this Croning or "C" process arose after it had been briefly described by Wm. W. McCulloch in a postwar report on German technology (F.I.A.T. report No. 1168, U. S. Government Office of Technical Services, Washington), and had shortly thereafter benefited from the publicity accompanying sale of "patent" rights. McCulloch's observations were made in the Hamburg plant of Johannes Croning & Co. It was also understood that components for some 6000 hand grenades were made daily by this process at Haller Werke in Hamburg. The New York Naval Shipvard started experiments in its material laboratory in 1947 to devise the best ingredients and techniques and to evaluate the castings so produced. While much work has also been done by the American foundry industry, it has been shrouded in secrecy due to the clouded patent situation, so that the technical information is contained in publications by Navy metallurgists, notably Bernard M. Ames, Seymour B. Donner, and Noah A. Kahn. The three published "Metallurgy of Shell Molding" in American Foundryman for January 1952, and "Plastic Bonded Shell Molds" in Foundry for August 1950. Mr. Ames presented a supplementary discussion on "Shell Molding" before the Malleable Founders' Society on Sept. 20, 1951,

The writer had an opportunity to observe the process during a recent visit to the

New York Naval Shipyard at Brooklyn, and to discuss the details with Mr. Kahn, head metallurgist; Mr. Ames, senior metallurgist; and Mr. Donner, associate metallurgist; as well as Capt. H. T. Koonce, U.S.N., director of material laboratory, and Charles E. Fraser, superintending engineer.

The object of my visit was to assess the practicability of shell molding, and to evaluate the evidence supporting the belief that it is likely to be a really useful addition to the

# An Appraisal of the Shell Molding Process

foundry industry. The definite answer to this question is yes, in the opinion of the writer, even though it must be borne in mind that any statements made concerning a brand-new process are liable to drastic modification as it is gradually perfected.

#### GENERAL REQUIREMENTS

Alloys best suited to shell molding seem to be cast, malleable, and nodular irons, manganese and aluminum bronzes, aluminum alloys, magnesium alloys, silicon bronzes, tin bronzes of low lead content (5.2 max.), and alloy steels. With magnesium alloys there is no need for inhibitors in the molding materials, such as are used for ordinary sand castings. Further improvement is required before low-carbon steels and high-lead bronzes can be classed as suitable. The former tend to have relatively rough surfaces, the latter to sweating out of the lead component.

While there is no obvious limit to the size of casting that might be made, in the present pioneering stage, castings up to 50 lb. are considered practical. However, cost will enter into the picture, since really large

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#### Casting to Close Tolerance

castings are generally not ordered in sufficient quantity to justify the pattern expense.

A principal requirement for practical use of shell molding is that a sufficient number of castings be made from any given pattern to justify the cost of the metal pattern plate. The process may also be advantageous where expense can be saved by the reduction or complete elimination of machining cost, together with greater dimensional accuracy. The saving of machining cost is particularly important with alloys by considered hard to machine. In such in-

generally considered hard to machine. In such instances, a much smaller number of castings from the pattern plate may justify use of the process.

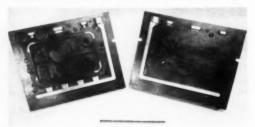
Tolerances compare favorably with the lost-wax investment process and plaster molding in castings of equally large size. For example, plates 18 x 12 in, with bosses and cored holes can readily be made within a tolerance of 0.003 in, per lineal inch. At the same time the process is simpler in operation, once the metal pattern has been accurately made. (Of course, investment casting requires the preliminary manufacture of a metal mold of high precision in which the wax or plastic model is made.)

Figure 1 shows a metal pattern plate used for shell molding. A requirement of the metal is that it shall not be distorted upon repeated heating, even to 1000° F.—the temperature required for curing certain desirable thermoplastic mixtures. This temperature also eliminates the possibility of repairing or adjusting the pattern plates

with the fusible solders ordinarily used. Suitable pattern plate materials, therefore, are alloy cast iron of the kind intended for high-temperature use, or the "nonshrink" and "graphitic" steels. Still other alloys may be found suitable as future experience dictates.

Gating (and risering if required) follows the

Fig. 1 — Master Pattern Plate Used in Shell Molding



conventional methods used for ordinary sand molding, with bottom gating given the preference. The mold material used is more insulating than foundry sand, and the risers can therefore function more effectively, since a better opportunity is provided for those parts of the casting that cool first to secure molten metal. There is no advantage to be had from the steel shot, as far as thermal conductivity is concerned. Replacing steel shot with copper shot does not influence the grain size of the casting (all other things being equal); in fact, comparison castings made in green sand have much finer grain size.

Formulation of the mold material is, of course, a most important factor. It consists

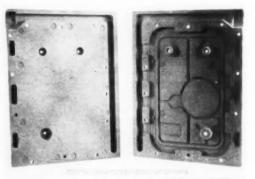


Fig. 2 — A Pair of Shell Mold Halves Produced From the Pattern Plate Shown in Fig. 1

essentially of a high-grade silica sand of subangular grain class (say 92 to 95%) with some 8% or less of pulverized resin capable of heat polymerization. The ingredients may be mixed in an ordinary Simpson muller, but it is desirable to cover the muller to prevent the escape of fine dust. In a large installation it would probably be desirable to exhaust the dust by a suitable suction connection to an elementary small baghouse. It has been suggested that the charges of static electricity acquired by the particles help in the uniform coating of the sand grains. If this is so, then anything that will cause a discharge of such static electricity should be avoided. Resin and sand must be thoroughly mixed; otherwise, the resultant mold will have a mottled appearance caused by undesirable resin segregation. Figure 2 shows a pair of shell mold halves produced

#### Resin-Sand Mixture

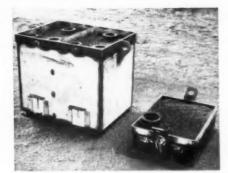


Fig. 3 — The Finished Mold Bedded in the Steel Shot and Ready for Casting

from the master pattern plate in Fig. 1.

Large quantities of resin or of the resinsand mix should not be stored, since polymerization will progress slowly under varying conditions of humidity and temperature, and a "balling up" may result. The resin might be put in solution before incorporating it with the sand, but sufficient work has not yet been done to justify the idea, and good results have been obtained consistently by the dry-mix method. The mold material is a complete loss after the molten metal has been poured, but this is not a serious drawback.

Another material needed is the releasing agent with which the pattern plate is sprayed to avoid sticking of the investment material. A water emulsion of 2 to 5% silicone concentrate is used. Spraying is done immediately after the pattern plate is removed from the heating oven.

Stripping the plates by hand is not recommended because the pressure cannot be evenly distributed and a twisted mold results. It is important to avoid warping of cope and drag (the mold halves) so that when they are fastened together (either immediately or after storage) the two parts will fit perfectly, thus avoiding fins on the casting. The critical period for warping is the first 60 sec. after the mold is released from the pattern plate.

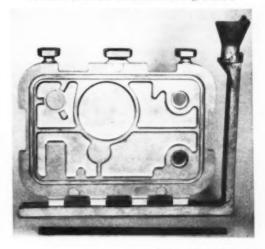
Molds may be closed in a variety of ways. Merely clamping the outside edges with spring wire is a common method. Preferred practice at New York Naval Shipyard is either to bolt the molds together, using Speednuts and an electric torquecontrolled nut runner, or to paste them together so as to minimize finning and reduce cleaning-room costs.

The backing material for supporting the shell mold during pouring is simply fine steel shot of about 16 mesh. An iron or steel frame of suitable size and depth to hold the mold and risers is used. The mold (cope and drag suitably bolted together) is laid on a bed of shot and more shot is poured around it to a level slightly below the rim, with the gate protruding (Fig. 3). In some instances a suitable pouring cup of dry sand is joined to the gate. The mold is then ready to pour (Fig. 4). In general, it is preferable to cast molds on edge rather than flat, though both methods can be used.

#### MOLDING AND CASTING PROCEDURE

A typical procedure, as observed at New York Naval Shipyard, starts with heating the cold pattern plate in an ordinary core oven to, say, 400° F. The temperature depends upon the conditions prevailing, such as kind of resin used and method of mixing. (Plates in a fully mechanized operation may also contain electrical resisters.) The first heating of the cold plate may take up to half an hour; the warm plate of course takes less time. The plate is removed and placed face downward in the container for the investment mixture. The container and plate are

Fig. 4—A Representative Aluminum Casting Produced From the Mold Shown in Fig. 2 and 3



#### Making the Mold

clamped together and turned over, whereupon the investment material falls on the hot plate. The investment material is softened by the heat of the plate in a matter of seconds. The container and plate are again reversed, and the excess material falls back into the container leaving about 1/8 to 3/6 in. of material of a putty-like consistency adhering to the plate. The coated plate is then carefully placed in the curing oven at approximately 600° F. for about a minute. Time and temperature of curing are carefully predetermined according to the requirements of mixture and ingredients. The finished mold is separated from the plate by suitable release pins incorporated in the pattern plate. It is hard and somewhat brittle, and the color of sulphur, the shade varying with the ingredients. The mold is laid on a flat table while still hot and weighted down with small sand bags for about a minute. It may then be either stored for future use or clamped to the other half (cope and drag), placed in the box backed up with shot, and poured. The total time for making the molds is 2 min. or less.

The final mold is not hygroscopic and may be kept indefinitely. It is also very permeable, which aids the escape of gases. It is sufficiently strong so it will not break easily with ordinary handling precautions.

A slight odor of ammonia while the mold is cooling comes from the decomposition of the resins. The color of the mold is eggshell white before curing; when cured it is a sulphur yellow. After casting, the surface which comes in contact with the molten metal is black but the back of the \(^3\_{16}\)-in. section remains yellow.

Pouring temperatures are similar to conventional sand molding temperatures. It should be borne in mind that freedom from shrinkage rather than maximum strength should be the criterion. Frequently a higher temperature will avert shrinkage (probably because of a higher gas content) and is to be preferred to use of a lower temperature.

In the operations observed at the shipyard, 800 castings were made from one pattern with only two defectives. Where optimum pouring temperatures were not adhered to, only 85% were good and 15% defective.

After the mold has been cast the shot must be removed and the casting extricated.

In the process some small pieces of the mold get mixed in with the shot. To remove the larger pieces the shot is screened through a ½-in. sieve. The small pieces of mold remaining give no trouble. In continuous operation, however, the shot will gradually heat up and provision will have to be made to cool and clean it.

The prime purpose of the backup material is to resist deformation of the mold wall and the hydrostatic head of the metal pressure. The use of shot represents one of the critical material handling problems in the whole process. Such problems as overheating, cleaning fines from the shot, loss due to spillage, and the safety hazards involved when loose shot is on the floor in the pouring area have not been completely or satisfactorily resolved. It is highly likely that this material will eventually be replaced by some other backup material or some other technique. Whatever material is adopted, it should be vibrated during backing up and should have good permeability -an important factor in venting gases.

A first essential of the process is extreme care in making the cast iron pattern plate. It must be well designed if production difficulties are to be avoided. This is a job for a good tool and die shop or a pattern shop used to making accurate metal patterns and effecting quick changes in gating and heading. The fact that the molds can be stored or transported from one plant to another frequently does away with the necessity of making a separate plate for use in each plant.

Cores are made on metal plates and procedure is similar to that for the metal pattern. They are hollow and collapse easily. If preferred, conventional cores may be used.

Once the pattern plate is made, the whole operation can readily be performed by previously untrained workers, girls being especially adept for small work. One large foundry got into production on shell molding in four months.

The future of the process will be associated with the development of automatic or semi-automatic machines. Fortunately, shell molding lends itself readily to mechanization. At least four machines embodying various mechanical methods of handling have already been developed, but it is probable that the machine for general adoption is still to come. Each user or designer is at present working out his own salvation.

VACUUM MELTING of magnetic alloys and some of the less common metals is now of considerable industrial importance, and occupies the attention of many specialists. Recent European work on this subject has been carried out at the National Physical Laboratory in England 1.21\* and the research laboratories of N. V. Philips' Gloeilampenfabrieken in Holland, 31\* and other research centers. Iron of reasonably high purity is required in substantial quantities to imple-

ment research on the effect of alloying elements on mechanical

properties of iron.

A unit for vacuum melting of iron in quantities up to 25 lb. is now in use at the National Physical Laboratory at Teddington, Middlesex. Starting with a selected batch of Swedish iron, the purification procedure was carried out on molten iron in

two main stages: (a) oxidation of a number of impurities and removal of the products of oxidation, and (b) a vacuum treatment for degassing, followed by reduction of oxygen to a low level by dried hydrogen.

The equipment consists of two highfrequency induction furnaces, one a 75-lb. tilting furnace for melting under oxidizing conditions, and the other a 25-lb. furnace for melting under hydrogen. Both furnaces are operated by a 30-kw. motor-generator set, delivering power at a frequency of 5000 eycles. A cutout switch is set at 660 volts and 54 amp. The cooling water operates a relay on each furnace, which switches off the power if the water pressure is insufficient. Below the coil in the Sindanyo base of the 75-lb. furnace is a charge-earthing device, which switches off the power in the event of the melt breaking through the magnesite lining.

The ingot mold used with the 75-lb, prerefining furnace is split; it is made of mild steel, and is 4 in. in internal diameter, 7 in. external diameter and 24 in. long. No dressing is applied to its internal surface, and no trouble is experienced with sticking or "burning on" of the ingot, provided the stream of molten metal is directed onto the existing pool and does not impinge on the side of the mold.

The 25-lb. furnace for final degassification is enclosed in a horizontal cylindrical mild steel tank (see Fig. 1 and 2). The tank is 4 ft. in diameter and 4 ft. 6 in. long; the end is closed by a domed lid, sealed by a tongue and groove with an intervening rubber ring. The tank is evacuated by two rotary pumps through pipe 8 in. in diameter. The furnace can be tilted by a chain and gear arrangement. A separately counterbalanced mold, placed in front of the furnace, is tilted with the furnace when the metal is poured at the end of a run.

# European Experiments on Vacuum-Melted Pure Iron

The leads to the furnace coil are flexible, and are covered with rubber tubing ¼ in. in wall thickness, to provide insulation and carry the cooling water. The leads enter the tank through an insulating plate, sealed with clamped rubber rings. One of the three openings on top of the tank is closed by a glass plate so the melt can be inspected from above. A second opening is fitted with a Wilson seal, through which a rod is attached to the refractory lid of the furnace. The lid can thus be turned, raised or lowered without leakage of air into the tank. The third opening is fitted with an eccentric sliding valve consisting of two circular plates with off-center holes. The holes can be matched by relative rotation of the plates over their lapped contact faces, the hole in the bottom plate being vertically over the third opening in the tank. A sheathed thermocouple placed in a Wilson seal screwed into the hole in the top plate can be lowered into the melt. The thermocouple sheath can be replaced by a dip-stick to obtain samples

<sup>\*1. &</sup>quot;Production of High-Purity Iron and Iron Alloys on a 25-Lb. Scale", by B. E. Hopkins, G. C. H. Jenkins and H. E. N. Stone. Journal of the Iron and Steel Institute, August 1951, p. 377.

 <sup>&</sup>quot;Tensile and Impact Properties of Iron and Some Iron Alloys of High Purity", by W. P. Rees, B. E. Hopkins and H. R. Tipler. Journal of the Iron and Steel Institute, October 1951, p. 157.

<sup>(3) &</sup>quot;Ageing of Iron and Steel", by J. D. Fast, Iron & Coal Trades Review, April 14, 1950, p. 837.

#### Furnace and Auxiliary Equipment

of the melt at various stages of purification. Additional sightholes are provided in the lid and on one side near the tilting wheel to view the pouring operation.

Figure 3 shows the arrangement of auxiliary equipment for the 25-lb. furnace and the course of the hydrogen flow. Dried hydrogen is drawn into the tank by a small rotary pump, and is passed through a filter and a tube leading through the crucible lid onto the surface of the melt. Water vapor is formed by reaction of hydrogen with the oxygen in the iron, and the moist hydrogen is drawn out of the tank through a furnace containing magnesium turnings at 600° C. (about 1100° F.), to remove nitrogen, and then through a cooler consisting of a cylinder of cold magnesium turnings. Outside the

vacuum tank, the hydrogen passes through a water-cooled coil, in which a small amount of the water vapor may condense, and into a large cylindrical drier containing 7 kg. of silica gel. A duplicate train is used in the later stages of a run to dry the hydrogen finally. The capacity of the circulating pump is 120 cu.ft. per hr., and the volume of the furnace enclosure is 60 cu.ft. The melting crucible is made of sintered high-purity alumina and is 4% in. in diameter and 9½ in. long; it is packed all around with the same fired magnesite used to line the 75-lb. furnace.

The top inch of the packing is bonded with sodium silicate, so that it sets at room temperature and prevents the loose packing beneath from being drawn out during evacuation of the lank. At the same time it is sufficiently porous so air and any moisture

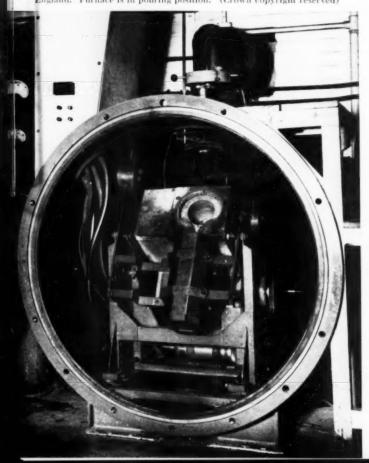
> can be removed. The main body of the packing is eventually sintered right through.

The ingot mold for the 25-lb. furnace is usually made of mild steel, and is octagonal in cross section, the distance across the flats being 2¾ in. internally and 6 in. externally. The mold is approximately 15 in. high, and the top 3 in. is turned out internally to a diameter of 4 in. to take a sillimanite insert, which operates as a hot top. Recently, a tapered mold of similar general design has been used. No dressing is applied to the mold surface.

#### OXIDIZING MELTS

The base iron is thoroughly cleaned of extraneous matter. Melting a 75-lb. charge takes about 1½ hr. The molten metal is allowed to oxidize for 1 hr., and the iron oxide formed on the surface is continually skimmed off. In early experiments it was found that the carbon content of the oxidized melts was reduced only to about 0.007 to 0.009% (oxygen 0.2 to 0.3%). Much sounder ingots of oxidized iron (increased in density by up to 20%) are obtained by blowing nitrogen or

Fig. 1—Apparatus for Melting and Casting a 25-Lb. Charge of Iron in Vacuo Used for Experiments at National Physical Laboratory, England. Furnace is in pouring position. (Crown copyright reserved)



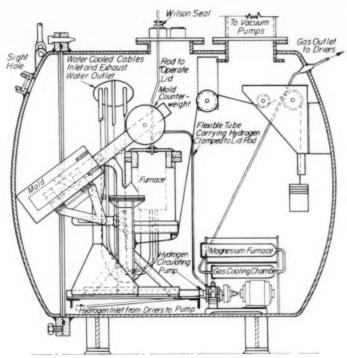


Fig. 2 — Section Through the Steel Tank and Furnace Shown in Fig. 1. (Courtesy *Journal* of the Iron and Steel Institute)

argon onto the melt in the 75-lb. furnace (after the 1-hr. oxidation treatment) for 20 min. to remove carbon monoxide. This procedure has been adopted as standard practice, and it does bring carbon content down to much less than 0.008%; results are not, however, as consistent as the later vacuum treatment in the 25-lb. furnace.

Some of the unsoundness in the oxidized iron ingots, and the evolution of gas in the subsequent vacuum treatment, may be caused by hydrogen formed from the water vapor in the atmosphere. Experience has also shown that the form of the charge influences the carbon content; for example, if the Swedish iron consists of strip or rod instead of heavier sections, the carbon content of the oxidized iron is as low as 0.002%.

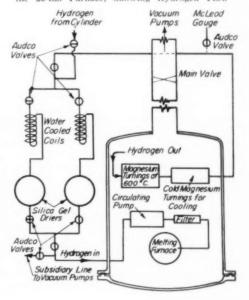
The oxidized melts are usually analyzed for carbon, silicon, and sulphur, and run about 0.002 to 0.005% C, 0.002 to 0.003% Si, and 0.004 to 0.006% S. Vacuum fusion analyses of two oxidized irons showed an average of 0.28% oxygen and 0.01% nitrogen. The oxidized iron ingots are machined to remove

#### Reducing Melts

surface scale, and cut into lengths suitable for melting in the 25-lb. refining furnace.

Reducing Melts - The metal for the 25-lb. furnace is first cleaned with carbon tetrachloride and dried before charging in the crucible. After the mold and its support have been clamped in position, the tank is closed and evacuation commenced. When a new crucible is used, it is normal to heat the charge to about 1000° C. (1830° F.) to degas the refractories; after cooling, a pressure of 0.001 mm. of mercury is usually obtained. Such a "heating run" is not conducted if the crucible has been used previously; the time required to reach the limiting pressure then depends on how long the tank has

Fig. 3 — Diagram of Auxiliary Equipment for the 25-Lb. Furnace, Showing Hydrogen Flow



#### Adding the Alloys

been open after the previous run. If melting was carried out on the previous day, the tank is opened in the morning, and evacuation for the next melt can usually be started in the afternoon; pressures of 0.005 mm. of Hg are obtained in about 1 hr., and 0.001 mm. in about 2 hr. Evacuation is continued for the rest of the day while the silica gel driers are reactivated.

The charge is heated slowly and melts in about 212 hr. The tank is filled with hydrogen from a cylinder to a pressure of 10 cm. of Hg during this stage, to prevent spurting from gas evolution while the charge is melting. By avoiding spurting, and by increasing the clearance between the solid charge and the crucible wall, initial troubles caused by bridging have been overcome. When the charge is all molten, the hydrogen is removed by opening the main valve connecting the tank with the pumps, and the melt is held for an hour in vacuo while the oxygen content is still high so as to reduce the carbon content. During this period the pressure drops fairly quickly to about 0.05 mm. of Hg, and remains at this level. The pumps are then isolated from the tank, and hydrogen is introduced to a pressure of one atmosphere. The hydrogen circulating pump is started, and hydrogen is blown onto the surface of the melt, passed through the furnace containing magnesium at 600° C. (1100° F.), through the coolers and one of the driers, and then back into the tank. Because of the high conductivity of hydrogen, approximately twice the power is necessary to keep the charge molten as would be required in vacuo.

When reduction is complete, hydrogen circulation is stopped, and the pressure is reduced to 5 cm. of Hg for ½ hr. to control hydrogen evolution from the melt and avoid splashing. The melt is poured at this pressure by simultaneous tilting of the furnace and mold. The ingot is allowed to cool overnight and is removed in the morning. A hydrogen pressure much above 5 cm. of Hg causes a gassy ingot, whereas if the pressure is much lower, there seems to be a greater tendency for the ingot to stick to the mold—presumably because of a less effective adsorbed layer of gas on the inner surface of the mold.

The temperature of the melt is checked periodically with a platinum/platinum-

rhodium couple. No sticking to the mold is encountered if the temperature is in the range 1565 to 1585° C. (2850 to 2885° F.) just before pouring, although care still has to be taken that the stream of molten metal does not impinge on the side of the mold at any one spot. This requires a little skill on the part of the operator, and although no trouble is now experienced, it has been suggested that the mold be rotated a few times during pouring, either mechanically or by an electric motor, to avoid prolonged impingement. It is possible that water cooling of the mold would also stop sticking, but this method is not convenient.

When making alloys, the additions are usually packed in iron sheet rolled from a deoxidized ingot, suspended from a crosspiece attached to the tube which holds the lid of the furnace, and lowered into the molten iron after it has been deoxidized. If the additions contain oxygen, the hydrogen treatment must be continued until it has been removed, since the oxides of certain additions are not reduced by hydrogen at the temperatures reached.

Chemical analyses of 35 iron and iron alloy ingots showed the following composition range:

Carbon	0.002 to 0.004%
Silicon	0.002 to 0.003
Manganese	0.004
Sulphur	0.004 to 0.006
Phosphorus	0.001 max.
Nickel	0.005 to 0.007
Chromium	0.001
Copper	0.004 to 0.007
Aluminum	0.001 max.

Aluminum may be higher than 0.001% if the melt has been accidentally overheated, or if the added alloy reduces the alumina crucible wall; some iron-carbon alloys have been made with aluminum up to 0.004%. Adoock has shown that thoria is not attacked by iron-carbon alloys, and if alloys with larger carbon content are desired, it may be necessary to use either thoria or thoria-lined crucibles.

Vacuum fusion analyses of 24 ingots ranged as follows:

Oxygen	0.001 to 0.002% by weight
Nitrogen	0.001 to 0.002
Hydrogen	0.000005 (trace)

These analyses were made on samples that had been hot rolled and normalized from 950° C. (1740° F.), and it will be seen that the hydrogen content is very low, even

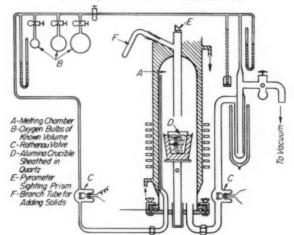
though the ingots were solidified in hydrogen at a pressure of 5 cm. of Hg. The hydrogen content in the cast condition is about 0.00007% by weight.

#### TESTS ON THE METAL PRODUCED

Physical tests of metal produced in this furnace have been published by Rees, Hopkins and Tipler (see reference 2, page 75). Results show that the purest irons prepared are very ductile at room temperature and at -73° C. (-100° F.) when tested in simple tension, but become brittle on cooling to between -73 and -196° C. (-320° F.). Fracture at -196° C, takes place by cleavage with less than 5% elongation at a stress of about 100,000 psi. - at least double the expected strength of high-purity iron at room temperature. The transition temperature in the Charpy impact test with Izod V-notch occurs at about -15° C. (5° F.). These results refer to material that has been chill cast, rolled, and normalized.

Iron prepared in the same way but containing more than 0.002 to 0.003% oxygen has properties very similar to those of highpurity iron in the ductile condition; however, when the iron is embrittled by cooling to -196° C. the tensile strength is much lower (60,000 to 75,000 psi.) and the fracture is partly intergranular and partly cleavage. The impact transition temperature

Fig. 4 — Small-Scale High-Frequency Melting Furnace Used by Dutch Scientists. The apparatus is built entirely of glass. (Courtesy Iron & Coal Trades Review)



#### Effect on Transition Temperature

rises with increasing oxygen content, and the brittle fractures are again partly intergranular.

The limit of oxygen content below which intergranular fractures are not encountered is less in irons of similar purity prepared in a 6-lb. furnace, in which the iron was allowed to solidify slowly in the crucible instead of being chill cast. Intergranular brittleness in an oxygen-containing iron can be enhanced by coarsening the grains through cold work and recrystallization.

The addition of up to 5% manganese to pure iron increases the yield stress and tensile strength; at -196° C. there is also an increase in ductility. No intergranular fractures were observed except in two anomalous alloys that had inferior properties. The tensile test results indicate that manganese raises the cleavage strength of iron more than it raises its yield stress.

Manganese decreases the impact transition temperature, provided that the distorted " $\alpha_2$  structure" is not present. This structure appears in the normalized alloys containing 3 and 5% manganese, and raises the impact transition temperature, but this effect can be removed by tempering.

Addition of 0.01% carbon to high-purity iron has little effect on the tensile and impact properties of normalized material. Additions up to 0.05%

raise the impact transition temperature appreciably, without a large effect on the tensile properties.

Addition of manganese to an iron containing 0.05% carbon progressively lowers the impact transition temperature, which, in an alloy with 2% manganese and 0.05% carbon, is lower than in a simple 2% manganese-iron alloy. Manganese and carbon together also lower the transition temperature in tension. The fractures, when not completely ductile, are cleavage type.

The transition from tough to brittle fracture in impact is usually very sharp in iron and iron-manganese alloys that fail entirely by cleavage in the brittle condition, but it tends to be less sharp when fracture is partly along grain boundaries. The addition of carbon to iron also spreads out the lower end of the transition, but the sharpness is progressively restored by additions of manganese.

#### Small-Scale Induction Melting

The transition from tough to brittle fracture in tension covers a range of temperature in iron-manganese and iron-carbon-manganese alloys, and it seems likely that this applies also to iron and iron-carbon alloys.

#### THE PHILIPS APPARATUS

J. D. Fast of the research laboratories of N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands, has developed a high-frequency melting apparatus on a smaller scale than that just described for pure iron. By adding fixed quantities of impurities, he has studied aging phenomena in iron and steel. One of the great advantages of an induction furnace is that melting can be carried out in an apparatus made entirely of glass, cooled with circulating water. Thus, the influence of the atmosphere and of gases released from the walls is almost entirely precluded. The apparatus can be evacuated to a pressure of 10 s atmospheres; if desired, it can then be filled with various pure gases. The crucibles were made of pure alumina, rendered impermeable by sintering at temperatures immediately below the melting point of alumina.

Figure 4 is a diagrammatic representation (not drawn to scale) of the apparatus. On the extreme right is the cock used to connect the melting chamber (about 41/2 in. inside diameter by 311/2 in. high) to the high-vacuum pumps. Cylinders of nitrogen, hydrogen, oxygen, argon, and carbon monoxide are manifolded and arranged so that each can be led through the purification train at will. Oxygen is admitted only in measured quantities, by using bulbs B of known volumes. In the inlet pipe and also in the outlet pipe of the melting chamber are Rathenau valves (C, C). These contain a ribbon of 18-8 chromium-nickel steel, which can be heated by an electric current and can detect traces of oxygen or water vapor in hydrogen, nitrogen or argon by heat tinting.

The alumina crucible D is contained in a larger crucible of clear quartz glass, the space between being filled with coarse pieces of alumina (fragments of discarded crucibles). The temperature of the molten metal can be measured by an optical pyrometer via a prism E.

To produce iron with a known content

of impurities, the Dutch scientists start with the purest grade of carbonyl iron (99,9% Fe with impurities almost exclusively carbon. oxygen and nitrogen). The nitrogen can be fully extracted by repeated melting in a vacuum, as can the carbon also, if the metal contains a large excess of oxygen; if the iron is low in oxygen in advance, a known quantity of oxygen can be admitted from the bulbs B. When all carbon has been driven out in the form of carbon monoxide, the excess oxygen is removed by passing a stream of pure hydrogen through chamber A for a prolonged period. The removal of oxygen can be checked at the Rathenau valve C. The hydrogen is removed, in turn, by melting in a high vacuum or in a current of argon.

The pure iron obtained in this way contains no more than 0.001% of carbon, oxygen and nitrogen, and the desired additions are then made. Solids can be added to the melt by turning the branch tube F. Carbon, if desired as an impurity, can also be added in this way in the form of pure graphite. If the substances to be added evaporate rather easily (such as manganese), the addition is made in pure argon instead of a vacuum. The additions blend homogeneously with the iron in a short time as a result of the circulation set up in the bath by electromagnetic forces.

Oxygen and nitrogen are added in the gaseous state. The equilibrium pressure of oxygen over liquid iron containing oxygen is negligibly small, so the oxygen added is entirely absorbed by the iron. The equilibrium pressure of nitrogen over liquid iron containing nitrogen, on the other hand, is great, so that only a relatively small part of the nitrogen added is absorbed. Moreover, when the metal solidifies, it gives off a large part of the absorbed nitrogen. As a consequence, the metal swells and, after solidification, shows large cavities.

To obtain nitrogenous iron without cavities, the procedure is as follows: While the metal is liquid (at about 1600° C.—2912° F.) the nitrogen pressure is reduced from 1 to 0.2 atmosphere, thereby reducing the equilibrium concentration in the metal from 0.046 to 0.021% nitrogen. The high-frequency current is then switched off and the nitrogen pressure immediately raised again to 1 atmosphere before solidification begins. The metal then solidifies to a compact mass and, after cooling, contains from

0.022 to 0.030% nitrogen. This effect can be understood to a certain extent from the solubility curve for nitrogen in iron. Smaller contents are obtained by choosing lower nitrogen pressures.

#### QUENCH AGING PHENOMENA

The Dutch apparatus was used to study the role played by oxygen, nitrogen and carbon in the aging of unalloyed iron and of manganese-containing iron. Pure iron was first prepared and known quantities of impurities were added, separately or together.

As shown by Vickers hardness determinations, carbon and nitrogen cause significant quench aging in iron that is otherwise pure. On the other hand, the quench aging of oxygen-containing iron is very slight. The addition of 0.50% Mn has no effect on the action of carbon, but practically suppresses the quench aging of iron containing nitrogen. This remarkable effect of manganese has been confirmed by determinations of damping. In experiments on the damping of torsional oscillations set up in wires, the maximum caused by nitrogen is broadened toward higher temperatures by the addition of 0.50% Mn. This can be explained by assuming that the nitrogen atoms are situated preferentially in the interstitial positions which are in the immediate neighborhood of a manganese atom. The damping observed indicates that the nitrogen atoms can make jumps around the atoms of manganese, but that they find it difficult to leave these atoms. Heating for some dozens of hours at 200° C. (392° F.) is necessary to precipitate a noticeable quantity of nitrogen in the alloys containing manganese.

Oxygen does not cause strain aging in iron. The essential cause of this phenomenon is nitrogen, less than 0.001% sufficing to produce the maximum strain aging. Even at room temperature, this aging takes place with great speed. Strain aging due to carbon only appears at a noticeable speed at elevated temperatures, such as 100° C. (212° F.). This difference between the effects of carbon and nitrogen apparently depends principally on the difference in their solubilities in iron. The time required for strain aging will be controlled mainly by the product of the diffusion coefficient and the solubility of carbon or nitrogen in iron. Manganese has no appreciable effect on the strain aging caused by carbon or nitrogen.

#### **Nominating Committees**

IN ACCORDANCE with the Constitution of the American Society for Metals. President JOHN CHIPMAN has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), and two trustees (for two years each). This committee was selected by President CHIPMAN from the list of candidates submitted by the chapters. The personnel is:

Chairman: Gilbert E. Doan (Lehigh Valley Chapter), Head, Department of Metallurgical Engineering, Lehigh University, Bethlehem, Pa.

W. B. Cheney (Fort Wayne Chapter), International Harvester Co., Pontiac St. & Bueter Rd., Fort Wayne, Ind.

J. W. Queen (New Jersey Chapter), Jos. T. Ryerson & Son, Inc., 16th and Bockwell St., Chicago 80, III.

Howard E. Boyer (Springfield Chapter), American Bosch Corp., Main St., Springfield 7, Mass.

A. B. Wilder (Pittsburgh Chapter), National Tube Division, U. S. Steel Co., 525 William Penn Place, Pittsburgh 30, Pa.

H. H. Heinisch (Toledo Chapter), National Supply Co., Toledo, Ohio.

B. T. Waddington (Western Ontario Chapter), Dominion Forge & Stamping Co., Ltd., 2480 Seminole St., Walkerville, Ont., Canada.

Gilbert S. Schaller (Puget Sound Chapter), Department of Mechanical Engineering, University of Washington, Scattle 5, Wash.

J. Y. McClure (North Texas Chapter), Manager, Quality Control, Consolidated Vultee Aircraft Corp., Fort Worth, Tex.

Also in accordance with revisions of the constitution adopted in October 1944, a committee for the nomination of secretary (for two years) has also been appointed, consisting of the president of the society as chairman and the six immediate living past presidents. Personnel of this committee is as follows: John Chipman, Chairman; Walter E. Jominy, Arthur E. Focke, Harold K. Work, Francis B. Foley, A. L. Boegehold, and Charles H. Herty, Jr.

THESE TWO committees will meet during the third full week in the month of May. They will welcome suggestions for candidates in accordance with the Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but individuals of a chapter may suggest to the nominating committee any candidates they would like to have in office. Endorsements may be sent in writing to either chairman or any member of either committee.

## By James H. Bechtold, Research Engineer, and Howard Scott, Manager Metallurgical and Ceramic Dept., Westinghouse Research Laboratories, East Pittsburgh, Pa.\*

M availability and good creep properties, is one of the most promising metals upon which to base new alloys capable of supporting useful loads at temperatures above 1600° F. However, some very serious difficulties must first be surmounted: Molybdenum forms a fusible and highly volatile oxide which rapidly consumes the metal when exposed to air above 1450° F.— a condition that may be improved by alloying.

its work hardening and recrystallization had disclosed means for rolling and annealing molybdenum so that a uniformly fine-grained and completely recrystallized structure could be obtained consistently. Particularly pertinent at the moment is the possibility of inherent differences in mechanical properties between "powder metallurgy" and "arc-cast" molybdenum.

Molybdenum cannot be melted and cast by conventional means. Nevertheless, chem-

ically prepared powder can be consolidated into ingots suitable for working into usable forms by either powder metallurgy or arc-casting techniques. The ingots produced by the two processes differ in chemical content, microstructure and mechanical properties, as may be seen from Table I. The higher carbon and lower oxygen in the casting result from the addition of carbon as a deoxidizing agent — apparently necessary to produce forgeable ingots. A deoxidizing agent

is unnecessary in powder metallurgy molybdenum, since sintering is done in a reducing hydrogen atmosphere.

In the as-cast or as-sintered condition, molybdenum is relatively weak and very brittle but, after suitable working and annealing, ductility at atmospheric conditions is excellent in both the work hardened and the recrystallized conditions. However, there is an abrupt transition from ductile to brittle behavior at temperatures slightly below atmospheric, and service applications will be largely governed by this transition temperature. The transition temperature is also believed to be an exceptionally sensitive criterion of differences in inherent ductility.

# Properties of Molybdenum Made by Arc Casting and Powder Metallurgy

Pure molybdenum has the reputation of being brittle at room temperature and its alloys would be expected to be even more brittle. Furthermore, it has a relatively low yield strength, which must be improved for engineering uses, and this requires alloying whether oxidation resistance is essential or not. Ductility is therefore a primary concern both in pure molybdenum and in its alloys, and we should know at least the major factors which influence ductility as measured by the tensile test.

Previous experience in other alloy systems and with molybdenum wire had shown that grain size plays a dominant role, ductility being higher the finer the grain. Complete recrystallization to an equiaxed grain was also found to be favorable, although in our early experiments annealing yielded a brittle molybdenum. Extensive studies of

#### METAL PREPARATION

The initial condition of the as-cast ingot is strikingly shown by Fig. 1. In contrast, the ingot derived from powder metallurgy is fine-grained and equiaxed and can be forged and rolled at relatively low temperatures (below the recrystallization temperature). Initial high-temperature forging or rolling breaks down the columnar grain of

\*The writers wish to acknowledge the assistance of J. W. Marden, manager of the molybdenum development department, Bloomfield Plant, Westinghouse Electric Corp. Also thanks are due to M. J. Manjoine for making the creep-rupture tests, E. T. Wessel for the tensile tests, and R. L. Anderson for the photomicrographs. The complete paper was presented at the April 1951 meeting of the Electrochemical Society.

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Fig. 1 — Are-Cast Ingot of Molybdenum. Natural size

the arc-cast (A.C.) ingot and it can then be worked into sheet or bars by the same procedure as the P.M. ingot. The small, equiaxed grain of the latter also facilitates the attainment of a fine final structure, since the only method of controlling the microstructure — which in turn largely controls the mechanical properties — is by work hardening and annealing.

For purposes of the test program to be described, rolling of both A.C. and P<sub>8</sub>M, bars required reheats between 2060 and 1700° F. (The A.C. was previously hot forged to break

down the cast structure.) The time of reheating was regulated to avoid recrystallization so the bars were effectively work hardened with a reduction in area of 91% (from 21s to 3s-in, round). Except for

a few molybdenum carbide particles in the arc-cast molybdenum, no nonmetallic inclusions were observed in the microstructure of either material after rolling. Both lots of metal were free from microporosity.

Test specimens were machined from the 5s-in. bars in the as-rolled condition and then annealed for 30 min. at 2100° F, in dry hydrogen. This produced the completely recrystallized and equiaxed grain structures shown in Fig. 2 and 3. Tensile and creep-rupture specimens had plain shoul-

Table 1 — Description of Material Tested

Consolidation Process	Arc-Cast	POWDER METALLURGY
Lot identification	A.C.	P.M.
Source	Climax Molybdenum	Westinghouse
Impurities	0.031% carbon 0.0002% oxygen 0.0056% nitrogen Spectrographic traces of Fe, Si, Cu, Mg	0.004% carbon 0.006% oxygen 0.0041% nitrogen Spectrographic traces of Fe, Si, Cu, Mg
Initial condition	21s-in, round billet as hot worked. Grain size No. 4.7	2 s-in, round ingot as sintered. Grain size No. 9.4
Rolling procedure	Rolled to %-in, round at 1900 to 1700° F.	Rolled to %-in, round at 1900 to 1700° F.
Microstructure as an- nealed 30 min, at 2100° F, and furnace cooled	Grain size No. 7.3 1200 grains per sq.mm. See Fig. 2	Grain size No. 7.8 1650 grains per sq.mm. See Fig. 3

Fig. 2 — Worked and Recrystallized Arc-Cast Molybdenum. Average grain size A.S.T.M. No. 7.3. Magnification  $100 \times$ 

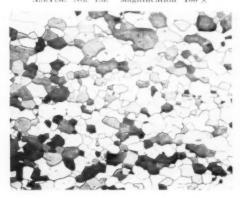
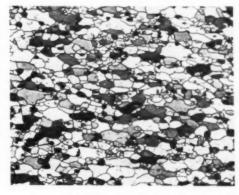


Fig. 3 — Worked and Recrystallized Powder Metallurgy Molybdenum. Average grain size A.S.T.M. No. 7.8. Magnification  $100 \times$ 



#### Tensile Properties of Molybdenum

ders (see Fig. 6); reduced sections were 0.252 in. diameter, gage lengths 1½ and 2 in. respectively.

Tensile specimens were pulled at a slow, approximately constant strain rate of 100% per hr., slightly slower than that ordinarily used for the "static" tensile test. The testing machine is somewhat special and has been described elsewhere; total deformation between crossheads is autographically recorded.

#### TENSILE TESTS

Stress-strain curves at several temperatures are replotted in Fig. 4. There is an abrupt change in the tensile properties at temperatures slightly below atmospheric. True stress at fracture and reduction in area (both uniformly distributed and at the neck) are plotted against test temperature in Fig. 5. Reduction in area values above 100° C. (212° F.) are probably low because of longitudinal splitting in the neck prior to transverse fracture. For this reason, the true stress at fracture is also somewhat uncertain. However, these conditions did not exist in the temperature range of most interest, namely, the transition from ductile to brittle fracture and below.

Both materials had pronounced upper and lower yield points, a characteristic commonly observed in metals with

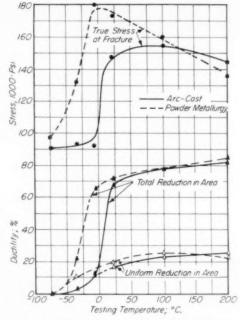


Fig. 5 — True Stress at Fracture and Reduction in Area Plotted Against Test Temperature

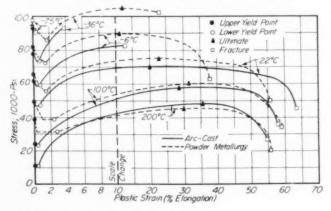
the body-centered cubic structure. In molybdenum this is also believed to be related to the nitrogen content. (It may be remarked, in passing, that the upper and lower yield points in annealed mild steel have also been correlated with nitrogen or carbon, or both.)

The curves for total reduction in area best

illustrate the abrupt transition from ductile to brittle behavior. If, for purpose of comparison, a "transition temperature" is defined as the point where the total reduction in area attains a value halfway between maximum and minimum values, it is +41 and -12° F. (+5 and -25° C.) for the A.C. and P.M. types of molybdenum respectively.

Above this transition zone both types have excellent ductility; below this zone both are completely brittle. The differences do not indicate any significant superiority for the powder

Fig. 4 — Stress-Strain Curves of Molybdenum at Several Temperatures Show an Abrupt Change Slightly Below Room Temperature

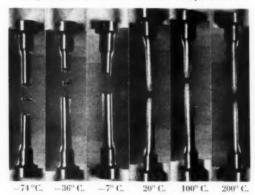


metallurgy product but can probably be attributed to a smaller grain size and normal variation, sample to sample.

The transition is also apparent from the fractured test specimens in Fig. 6. Double fractures at -101 and -33° F. (-74 and -36° C.) were probably caused by elastic shock waves; the P.M. specimens also had double fractures in this range.

Types of fracture were similar in the two materials. Below the transition temperature, fracture occurred through the grains, probably on the (100) crystallographic planes, with no measurable plastic deformation. The fractured surface was bright

Fig. 6 — Fractured Tensile Specimens of Arc-Cast Molybdenum Tested at Various Temperatures



-typical of the fracture observed in most brittle metals that fail by cleavage —and approximately normal to the direction of loading. Microscopic examination showed well-defined cleavage facets which had numerous strain markings, even in the specimens for which no measurable plastic deformation was observed.

Specimens tested in the transition range also failed with a bright, cleavage type of fracture, normal to the direction of loading. The cleavage facets had numerous strain markings and were rounded and somewhat distorted.

Specimens tested above the transition temperature had a dull, fibrous type of fracture, similar to the so-called ductile-shear fracture in mild steel.

\*Reported by F. F. Witman and F. A. Stepanoff, Journal of Technical Physics, U.S.S.R., Vol. 9, 1939, p. 1070; by H. E. Davis, E. R. Parker and A. Boodberg, Proceedings, American Society for Testing Materials, Vol. 47, 1947, p. 483; and by J. M. Hodge, R. D. Manning and H. M. Reichhold, Transactions, American Institute of Mining and Metallurgical Engineers, Vol. 183, 1949, p. 233.

#### **Abrupt Change in Ductility**

Numerous longitudinal splits were observed in the necked-down region, and, because of the large amount of plastic deformation, microscopic examination was difficult and inconclusive.

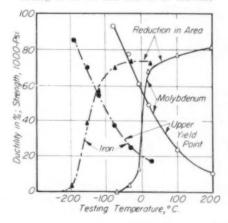
#### CAUSE OF TRANSITION IN DUCTILITY

An abrupt transition from ductile to brittle behavior is not a unique characteristic of molybdenum. Iron and ferritic iron-base alloys show a similar behavior at a much lower temperature. The striking similarity — except for a

difference in temperature — is illustrated in Fig. 7. Tungsten, tantalum, chromium and other metals that have a body-centered cubic structure will undoubtedly exhibit this behavior when tested under comparable conditions. It has not been observed in metals and alloys that have a face-centered cubic structure such as copper or austenitic steels.

The reasons for an abrupt transition have not been determined; however, many of the factors which affect its temperature have been identified. Work at Westinghouse Research Laboratories on molybdenum, plus numerous tests on steel,\* show that increased strain rate, stress conditions that restrain the flow of the metal, or an increase in the grain size will raise the transition temperature. Strain hardening induced by

Fig. 7 — Tensile Properties of Molybdenum and Annealed Ingot Iron as a Function of Testing Temperature. The iron contained 0.02% C, 0.058% O<sub>2</sub>, 0.002% N<sub>2</sub>, 0.005% P, and 0.018% S; grain size was A.S.T.M. No. 2 to 3. (According to G. W. Geil and N. L. Carwile)



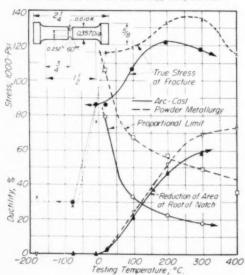
#### Notched-Bar Tests

rolling, forging or drawing lowers the transition temperature in the direction of metal flow—or, at least, tends to retain some ductility below the transition temperature. However, the ductility normal to the direction of flow is reduced by strain hardening. Nonmetallic impurities, such as carbon, oxygen and nitrogen that form interstitial solid solutions, probably raise the transition temperature. It would be interesting to know if body-centered cubic metals completely free of these impurities would behave in this manner.

The effect of one of the factors on the transition temperature can be illustrated by tests on notched tensile specimens. The notch inhibits plastic flow and concentrates local stress at the root. The specimen sketched in Fig. 8 has a sharp V-notch with a calculated elastic stress concentration factor of 3.1 at the root. Reduction in area, proportional limit and true stress at fracture for such specimens are also plotted. Comparing this figure with Fig. 5, we see that the transition from ductile to brittle behavior is 250 to 300° F. (120 to 150° C.) higher than for the standard tensile specimen.

Probably of greater importance than

Fig. 8 Notched-Bar Tensile Properties of Arc-Cast and Powder Metallurgy Molybdenum



the higher transition temperature is the very low stress at fracture below the fransition temperature. As shown in Fig. 8, these stresses are the average over the reduced area under the notch; however, because of the stress concentrations, a stress several times this average can occur. Above and in the transition range sufficient plastic deformation occurs at the root of the notch to relieve these concentrations, but below the transition temperature molybdenum behaves in an almost elastic manner and the stress concentrations are not relieved. This results in a high local stress; a crack starts and propagates at a very low average stress. If this average true stress at fracture is multiplied by 3.1, the axial stress concentration factor, the actual stress at the root of the notch at fracture is found to be approximately the same as that for the standard tensile specimens when tested at the same low temperature. These results illustrate the importance of avoiding sharp changes in contour in molybdenum parts that must support loads—especially dynamic loads — at temperatures close to atmospheric. The notched specimens failed with the same types of fractures as those observed in the standard tensile specimens.

It should be emphasized that our specimens were tested at slow strain rates. Accordingly, extreme caution must be used in applying room-temperature tensile data for predicting service behavior close to room temperature. A part fabricated from molybdenum may act in an entirely different manner if the loading conditions, such as stress system, strain rate and size, depart materially from those of the tensile test.

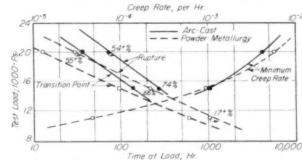
#### CREEP-RUPTURE TESTS

Creep tests have previously been made on molybdenum as reported by Scott in Metal Progress, Vol. 58, October 1950, p. 503, but his material was somewhat coarser grained and perhaps not as reproducible as that used in these later tests. On that account, it was fell that tests at a single temperature, 1600° F. (871° C.), would suffice for a comparison. The creep testing machine described by Manjoine in Transactions, American Society of Mechanical Engineers, Vol. 67, 1945, p. 111, was used with an atmosphere of hydrogen.

Data for our A.C. and P.M. molybdenum at 1600° F, are plotted in Fig. 9. Both have similar creep-rupture properties. The arccast variety had a slightly longer rupture life and slower creep rate at 20,000 psi, but not at 15,000 psi, so it is doubtful that there is any significant difference. Plastic strain at rupture is also recorded; it shows the high degree of ductility of molybdenum at 1600° F.

In Fig. 10 the 100-hr, rupture strengths of molybdenum, iron, cobalt and two of the better so-called superalloys are compared. The rupture strength for molybdenum at 1600° F, was obtained from Fig. 9, and at higher temperatures from tests reported by Scott (in the October 1950 Metal Progress article) on completely recrystallized but relatively coarse-grained swaged molybdenum bars. Iron and commercial cobalt, both in the annealed condition, were tested by J. K.

Fig. 9 — Creep-Rupture Data at 1600° F, in Hydrogen. The figures represent plastic strain at rupture



Figures Represent Plastic Strain at Ruplure

Stanley in this laboratory. The iron contained 0.012% carbon, 0.04 to 0.06% oxygen, and less than 0.01% total metallic impurities; the commercial cobalt, 0.011% C, 0.0043%  $O_2$ , 0.45% Ni, 0.07% Mn, and 0.12% Si. Refractaloy 70 is a wrought material, a

precipitation hardened, nickelcobalt alloy (Co 30, Ni 20, Cr 20, Fe 15, Mo 8, W 4, C 0.05), and Haynes Stellite No. 31 (or X 40) is a precision-cast cobalt-base alloy (Co 55, Cr 25, Ni 10, W 7.5, C 0.50).

When compared on the basis of equivalent 100-hr. rupture strengths. Fig. 10 shows that molybdenum has about the same rupture strength as iron does when 932° F. cooler, or cobalt does 572° F. cooler. The creep-rupture strength of pure nickel has not been reported, but it would

#### Comparisons of Creep Properties

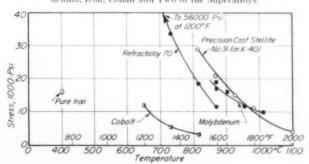
probably be intermediate between iron and cobalt. The rupture strength of iron, cobalt or nickel can be increased greatly by proper alloying (see the curves for Refractaloy 70 and Haynes Stellite No. 31), but even then their rupture strength above 1650° F, is no better than that of pure molybdenum. A considerable improvement in its creep properties should be possible by proper alloying. In fact, a 100-hr, rupture strength of over 30,000 psi, at 1600° F, has been obtained in pure molybdenum simply by work hardening, but such improvement is not feasible above the recrystallization temper-

ature, 1650 to 1750° F.

Figure 10 does not mean that pure molybdenum would be as good a material as the superalloys for normal hightemperature applications, especially where oxidation resistance or dimensional stability is required. Hot molybdenum oxidizes very rapidly in air or other oxidizing atmospheres. Even in a reducing atmosphere, pure molybdenum creeps very rapidly and a relatively large amount during the initial creep stage. This prohibits its

use where dimensional stability is important. This high initial creep can be partially eliminated by work hardening, but again it would eventually recrystallize above 1650° F, with subsequent rapid creep. The excellent ductility indicates that it should be possible

Fig. 10 — 100-Hr. Rupture Strengths of Molybdenum, Iron, Cobalt and Two of the Superalloys



#### Alloying for Improvements

to add a considerable amount of alloy, thereby improving first-stage as well as over-all creep strength, and still retain satisfactory high-temperature ductility.

#### SUMMARY AND CONCLUSIONS

Billets of arc-cast and powder metallurgy molybdenum were prepared in the fully annealed and completely recrystallized condition. Tests showed little difference between A.C. and P.M. varieties in tensile properties over a range of temperatures above and below atmospheric, or in creep strength at 1600° F.

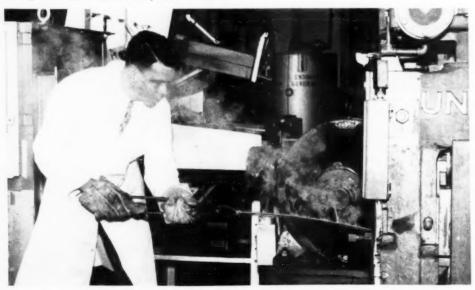
The cold brittleness of molybdenum was found to be associated with a well-defined transition from ductile to brittle fracture on a lensile test at a temperature only slightly below atmospheric. The brittle condition is characterized by a cleavage-type fracture such as occurs in iron near liquid air temperatures. Above the transition temperature, ductility is quite high.

Influence of stress distribution on the transition temperature was studied, using a notched tensile specimen with a theoretical stress concentration factor of 3.1. This condition raised the transition temperature to 257° F. (125° C.). The occurrence of this transition near room temperature and the pronounced influence of many factors call for meticulous control of fabrication for maximum cold ductility. Lowering of the transition temperature by alloying may be possible, as it is in iron, by the addition of a correct percentage of nickel.

The creep and rupture strength of molybdenum in the fine-grained annealed condition is high relative to other pure metals used for high-temperature alloys, and is superior to the best of the conventional alloys above 1650°F. Undoubtedly this property can be considerably improved by alloying and possibly some degree of atmospheric oxidation resistance could be conferred as well, with the retention of a reasonable amount of hot ductility.

None of the tests showed any significant difference between A.C. and P.M. molybdenum in a comparable structural condition, although there are considerable differences in their hot working characteristics. Differences in carbon, nitrogen and oxygen content may be responsible for the upper and lower yield points observed in both materials. Material of extremely high purity will have to be prepared and tested to answer the questions raised by these observations.

Fig. 11—A Hot Bar of Molybdenum-Base Material Being Rolled Into Strip in the Westinghouse Research Rolling Mill. The smoke is molybdenum trioxide



METAL PROGRESS: PAGE 88

## By W. H. Holcroft, Executive Vice-President and Technical Director and D. J. Schwalm, Metallurgical Engineer, Holcroft & Co., Detroit

A<sup>N</sup> ARTICLE in the December 1950 issue of Metal Progress dealt with the generalities of carbo-nitriding, such as background, scope, and classification. It ventured a rule-of-thumb classification of the many applications of the process, wherein Class I included a large majority of the commercial uses. In this class the object is to produce a light case by heating at medium temperatures (1450 to 1650° F.) in a carburizing gas carrying a low ammonia addition. Class II

comprises carbo-nitriding, at low temperatures (1200 to 1450° F.), parts of thin metal which might be expected to distort beyond acceptable limits in a normal hardening quench. Class III comprises duplex treatments to give hard cases and annealed cores in the part.

This article will attempt to substantiate some of the theories of the process by reporting certain laboratory and production experiences. It will deal with specific aspects of the common Class I process, such as the effect

of ammonia on case properties; the effect of rate of flow; the effect of CO-CO<sub>2</sub> equilibrium; and the effect of temperatures above 1450° F

As was pointed out in the first article, contradictory results in some of the articles published about the process are probably due to uncontrolled variations in the composition of the gas actually in contact with the work and uncertainties in the amount of nitrogen absorbed by the work.

To perform the type of confirmatory experiments we had in mind, it was first necessary to be able to measure the very small percentages of undissociated ammonia leaving the heating chamber, and determine the percentages of nitrogen added to the specimens. The first of these problems was solved by the perfection of a rapid and accurate analytical method of ammonia determination in effluent gases.

The other problem (nitrogen analysis of the metal) was somewhat more difficult. In our early laboratory work we took turnings from carbo-nitrided pieces and sent portions of a single sample to our own chemical laboratory as well as other cooperating laboratories. We were unable to get close checks between laboratories, so we finally discarded the direct chemical analysis for determining nitrogen. In most of our early work, therefore, results of various heat treatments were compared microscopically.

Figure 1 shows the results of an early group of four tests run in a laboratory furnace at 1510°F, using generator gas and varying amounts of ammonia and propane.

# Influence of Temperature, Gas Composition and Flow on Carbo-Nitrided Cases

They are interesting from the standpoint of hardness and the microstructure of the cases produced. The samples used for microscopic examination were light sections of S.A.E. 1020 steel. They were quenched in oil after 2½ hr. at temperature in the gas of the composition indicated in the caption below the micros. In all tests the total volume of gases passing through the furnace was kept constant at about 24 cu.ft. per hr.

#### FILE HARD CASES PRODUCED

The photomicrographs of the cases at 750 × indicate that increasing percentages of both ammonia and propane influence the amount of austenite retained in the case and also the amount of "white layer" produced on the surface. All of the test pieces were file hard; the Rockwell hardness seemed to vary inversely with the amount of untransformed austenite.

In the first test, 1-A, the atmosphere consisted of generator gas and  $2\frac{1}{2}\%$  propane. For the second run, 1-B, the propane was omitted and the atmosphere fed to the work

#### Structure of Carbo-Nitrided Cases

chamber contained generator gas and 11/1% ammonia. Both cases so produced are martensitic, but a small amount of austenite has been retained in sample 1-B; at a temperature of 1510° F., carbon monoxide supplied in sufficient quantity in the generator gas is considered to have carburizing activity. For 1-C, propane was again omitted and the ammonia was increased to  $2^{\frac{1}{2}}$  of the input gas; its microstructure shows a decided increase in the amount of austenite which has been retained, and also a white layer has begun to form on the very surface. For the fourth test, 1-D, the ammonia was kept at 212 and a like quantity of propane was added with the generator gas. The microstructure shows approximately the same amount of austenite as 1-C, with a definite increase in the depth of white layer; this seems to indicate that carbon is a constituent of this component at the surface as well as nitrogen. In all runs the time, temperature and quenching rate were the same.

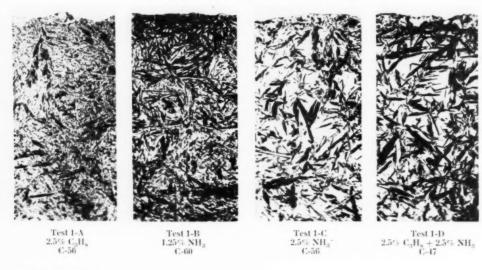
#### EFFECT OF VARIABLE AMMONIA

Subsequently, several series of laboratory tests were made to determine the effect wide variations in ammonia additions to the atmosphere would have on the nitrogen absorbed by the steel. A small laboratory furnace was used, having a retort 6 in. diameter by 6 in. long. Samples were low-carbon (0.07%) shim stock, 0.050 in. thick, ½ in. wide and 1½ in. long, which weighed approximately 5 g. Samples were accurately weighed before and after carbo-nitriding and the gain in weight recorded. The entire sample was analyzed for carbon and the difference between calculated weight gained by carbon and total weight gained was assumed to be the weight of nitrogen added to the steel. This could then be figured back to percentage of nitrogen.

In any one series of tests the temperature was maintained constant; time in furnace was also constant; the carrier gas and the natural gas flow was constant; the ammonia addition was the only variable. The carrier gas flow was maintained at either 32 or 45 cu.ft. per hr. When natural gas was used it was at 1 cu.ft. per hr. Continuous Orsat analysis and ammonia determinations of inlet and outlet gases were made. The ammonia in the inlet gas was varied from approximately 3 to 33% in the different tests.

The results of one series are shown in Fig. 2. These tests were all run at 1550° F.; time in the furnace was 1 hr.; generator gas flow was 32 cu.ft. per hr.; natural gas addi-

Fig. 1 — S.A.E. 1020 Heated 2.5 Hr. at  $1510^\circ$  F, and Oil Quenched.  $750 \times$ , Gas additions shown are to generator gas. Hardness numbers are converted from 15 N readings



tion was 1 cu.ft. per hr. From the data obtained it can be seen that as the percentage of ammonia in the inlet gas was increased. (a) the amount of nitrogen added to the steel increased, (b) the amount of carbon added decreased slightly, and (c) the Rockwell hardness progressively decreased. This is a point worthy of note because it has been our contention for a number of years that many industrial installations use unnecessarily large amounts of ammonia in their carbo-nitriding atmospheres. If ammonia is added solely to increase the nitriding potential of the atmosphere and not to counteract poor carrier gas conditions, it not only decreases hardness (and wear resistance) but also increases production costs.

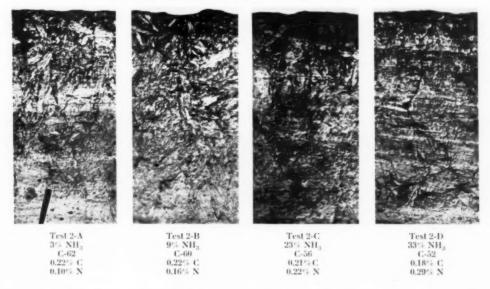
The carrier gas for these tests conformed to American Gas "Assoc.'s Type 302.★ In

#### Penetration of Carbon and Nitrogen

by Orsat analysis. Carbon would be absorbed by the hot metal at a slower rate through either dilution of CO by  $N_2$  (reducing the number of contacts between metal and carburizing gas) or through the presence of small amounts of  $CO_2$  (which shift the equilibrium of the reaction  $3\,\mathrm{Fe} + 2\,\mathrm{CO} \rightleftharpoons \mathrm{Fe}_3\mathrm{C} + \mathrm{CO}_2$ ). When these runs were repeated using a generator gas containing a higher percentage of carbon monoxide, the amount of carbon absorbed returned to the same level as in the lower ammonia runs, 2-A and 2-B.

While carbon and nitrogen in this series are reported as per cent, this is the per cent of weight gained by the sample, and is not intended as concentration of either element

Fig. 2 — First Series of Tests on 0.07% C. Shim Stock, Oil Quenched After 1 Hr, at 1550 F. (These and remaining micrographs in this article are at 500 ×.) Atmosphere consisted of 32 cu.ft, per hr, of generator gas, 1 cu.ft, per hr, of raw natural gas (principally methane), and a variable amount of ammonia as indicated. Figures for carbon and nitrogen are computed from weight gains and represent average for whole thickness



Tests 2-C and 2-D, wherein a large volume of ammonia was added, the carbon monoxide in the furnace gas was reduced by dilution to about 10%. It is believed that the slightly lower carbon addition in these samples than in 2-A and 2-B was caused by a changed (CO)<sup>2</sup>/CO<sub>2</sub> ratio undetectable

\*This is an endothermic base, completely reacted by 2½ times as much air as 1000-B.t.u. natural gas, and quickly cooled to eliminate sooting of CO. Its representative analysis is 39.8% N<sub>2</sub>, 20.7% CO, 38.7% H<sub>2</sub>, 0.8% CH<sub>4</sub>. It is combustible, toxic and very reducing in nature when in contact with iron oxides at heat treating temperatures. See *Metal Progress* Data Sheet for August 1947, p. 256-B.

#### Effect of Temperature

in the case. Microscopic examination of the pieces showed total penetration of approximately 0.015 in. to be quite uniform in all the samples.

In Fig. 2, a variation in the depth of hardened case can be noted. This may be due to slight differences in quenching rates caused by the difficulty in moving such a small piece of steel from the work chamber through air to the oil quench, several feet away, without slight variations in the temperature of the samples. This difficulty is not

encountered in production, where proper design of equipment insures uniform processing of all pieces. Furnace cooled samples, in which quenching was not a factor, showed the total penetration to be quite uniform for all four gas concentrations. In these tests the quenched and furnace cooled samples were processed simultaneously for each gas concentration. The oil quenched samples

were used for microscopic examination, while the furnace cooled samples were used for carbon and nitrogen determinations, as well as for microscopic examination.

Figure 3 shows the effect of temperature on case structure. Furnace conditions were the same as 2-D with the exception that each sample was run at a different temperature, and 3-A at 1450° F. was run with a lower

percentage of ammonia in the inlet. As would be expected, increasing the temperature of carbo-nitriding has the following effects: (a) The amount of nitrogen absorbed decreases, because of the lower nitriding potential of the atmosphere: (b) the compound layer formed at the lower temperatures disappears, because of higher diffusion rates and the decrease in nitriding potential of the atmosphere: (c) the amount of carbon absorbed increases, because of higher diffusion rates: (d) the Rockwell hardness increases, because of combined increase of absorbed carbon and decrease of absorbed nitrogen; (e) the case depth increases, because of the higher diffusion rates.

Figure 4 shows the effect of rate of flow of the furnace

Fig. 3 — Effect of Temperature on Case Structure of Sample 2-D. (Sample 3-B is the same as 2-D.) Figures for carbon and nitrogen are grams of element added to the entire sample (0.050 x 0.50 x 1.50 in.)



Test 3-A 1450° F, 23 ° NH<sub>3</sub> C-48 0.0065 g, C 0.0206 g, N



Test 3-B 1550° F. 33% NH<sub>3</sub> C-52 0.0085 g. C 0.9144 g. N



1700° F. 33′ NH<sub>3</sub> C-64 0.0093 g. C. 0.0131 g. N

#### Effect of Gas Flow

atmosphere. These samples were run under the same conditions otherwise as the two previous series, with the exception that no natural gas was added to the atmosphere and changes were made in the composition of the carrier gas. The CO was raised from 20% to 35% by adding carbon dioxide to the mixture of air and natural gas reacted in the standard Type 302 generator. This was done to increase the carburizing power of the generator gas and to show the importance of carbon monoxide as a carburizing medium. A comparison of the amount of carbon absorbed in this series and Test 3-B (Fig. 3) seems to confirm this belief. The amount of nitrogen absorbed in these samples is less than in the tests shown in Fig. 3 and this is believed to result from the disturbance of the equilibrium between NH3, H2 and N2. The carbon dioxide going into the gas generator reduces the percentage of hydrogen in the carrier gas and, therefore, reduces the stability of the ammonia - it dissociated enough to tend to replace the missing hydrogen.

As shown in Fig. 4, increasing the flow of the furnace atmosphere above the minimum necessary for consistently good results has little or no effect on the amount of carbon added. It does, however, slightly increase the amount of nitrogen absorbed by the hot steel.

In summarizing, it can be concluded that increasing the temperature of carbo-nitriding causes:

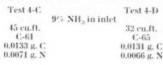
- A decrease in the amount of nitrogen absorbed.
- An increase in the amount of carbon absorbed.
- A decrease and eventual disappearance of a white layer.
- 4. An increase in the Rockwell hardness. An increase in the percentage of ammonia in the furnace atmosphere for a given temperature causes:
- An increase in the percentage of nitrogen absorbed.
- A decrease in the amount of carbon absorbed.
- A decrease in the Rockwell hardness. An increase in the rate of flow of the furnace atmosphere within reasonable limits has little effect other than slightly increasing

the amount of nitrogen absorbed.

Fig. 4 — Excessive Rate of Flow of Atmosphere Has no Effect on Carburizing Action, and Slightly Reduces the Nitriding Action. Tests 4-A and 4-B are one pair; 4-C and 4-D are another. Specimens oil quenched after 1 hr. at 1550° F.







## Correspondence\_

#### Refining Steel With Oxygen

KAPFENBERG, AUSTRIA

A symposium on the refining of steel with oxygen was held in December 1951 in Leoben. Austria, which may be of especial interest to American metallurgists, since the method will be used for producing nearly one quarter of all Austrian steel this year. It is especially suitable for the blast furnace iron available in this country, whose composition is 3.7 to 4.3% C, 0.2 to 1.0% Si, 1.6 to 3.0% Mn, 0.08 to 0.20% P, and 0.08% S max. Molten iron is being blown to steel without any external source of heat in the following manner:

Basic converters of 5 to 15 tons capacity. of the side-blown design, while in the upright position receive a proper charge of molten pig iron. (As a matter of fact, the original experiments were made in a hotmetal ladle at the Linz works of the Vereinigte Österreichische Eisen und Stahlwerke.) A vertical, water-cooled pipe about 1 in. diameter is lowered into the vessel through the mouth until its end just clears the top of the bath, and oxygen is blown through for 18 to 20 min. Oxygen consumption is 1950 to 2000 cu.ft. per ton of finished steel. About 20% scrap is needed to keep the temperatures within limits. Nitrogen in the finished steel is 0.006 to 0.008% when the oxygen carries no more than 2% N, but increases to 0.016% when a crude 75:25 O2:N2 mixture is blown on the bath. Phosphorus is brought down to 0.03% in the 15-ton vessel.

It was pointed out by K. Rösner that costs are lower than the conventional pigand-ore process in the openhearth, particularly if the scrap does not need to be carefully sized before charging. Other commentators testified that the quality of such steels was equal to or better than openhearth steel as to its hot and cold working properties, stability (nonaging) and weldability.

There are clearly several advantages in this system. The separation of the oxygen supply from the converter means that difficulties in preserving the tuyeres from damage during the filling and emptying of the vessel are entirely avoided as well as difficulties with pipe connections and with water coolers when the vessel tilts. But principally there is the fact that, during conversion, the point of maximum heat development (that

is, the point where the oxygen stream impinges on the metal) is removed as far as possible from the walls of the vessel. Thus at one stroke all the old trouble with excessive tuyere consumption and rapid failure of the converter lining is avoided.

M. Hauttmann discussed the mechanism of the process, saying that direct oxidation occurs mainly and very rapidly at the region near the end of the oxygen pipe (creating local temperatures so high that oxides of iron and manganese actually volatilize). This region of rapid reaction may be regarded as a hemisphere with the oxygen pipe at its center; the metal in this sphere is stirred violently and it continuously works out into the surrounding metal, being replaced with other metal containing more of the oxidizable elements carbon, silicon and manganese. Metal leaving the hot center carries with it considerable oxygen which reacts with the bath some distance away.

> Franz Rapatz Technical Director of Steel Works Gebruder Böhler & Co.

#### High Temperature Scale Resistance

PARIS, FRANCE

Getting good chemical resistance at high temperatures out of metals and alloys requires application of some general principles that we pointed out long ago and which we can review summarily here. To increase oxidation resistance of a metal, a solute element must be added which in itself oxidizes more readily than the solvent metal but whose oxide is more refractory than the oxide of the solvent - that is, the oxide must not melt nor sublime - and whose oxide is impervious and adherent. In other words, it is the physical properties of the oxide (refractoriness, density, plasticity, permeability, and such) that must receive consideration.

In view of this it is well to consider those refractories used in industry, and in particular in metallurgical processes. These refractories are based on silica, alumina, and chrome oxide, or lime and magnesia (used in the basic steel refining methods), or zirconia, beryllia, and thoria (used for laboratory equipment), or lastly the rare earth oxides (for incandescent gas mantles).

If iron is to be the base metal, calcium and magnesium must be omitted from this list of possibilities since they do not alloy with iron. Among the other elements that could be used, we find those very elements that are found in heat-resistant steels, notably chromium, silicon, and aluminum. We have already noted (in 1934) the relationship between the amounts of these different elements necessary to confer oxidation resistance on the steel and the atomic weights of these elements.

There is the possibility of adding several of these elements at once, for example, silicon, chromium, and aluminum, as in "sichromal", but new considerations arise here. For the oxide layer to be protective it. must prevent union of the attacking gas and the underlying metal. Omitting the consideration of porous scales (which have been discussed by Pilling and Bedworth and more generally by Trombe) we can see that union of the reactants will occur through compact scales by diffusion of the ions of either metal or oxygen. This immediately involves the ionic and electrolytic conductivity of the scale (Wagner, Mott) and the necessity for a concentration gradient. Thus the best protection will be given by oxides that have no range of solid solution or which are pure homopolar compounds.

In line with these remarks, it should be noted that electrolytic or ionic conductivities behave just the opposite to electronic (metallic) conductivity. High temperatures or solid solution increases these types of conductivities. In his studies on lanthanium and titanium oxides, Trombe finds that solid solution increases conductivity, whereas solid solution of the metals themselves decreases metallic electronic conductivity. Solid solutions of ZrO<sub>2</sub> and MgO furnish an example of solid solution. In this instance we find a direct substitution of magnesium atoms (see André Michel, Société Chimique, Meeting of Jan. 26, 1951).

Consequently, if more than one oxide forms at the surface of the metal, it is important that they exist as a mechanical mixture and not as a solid solution.

These principles for obtaining good oxidation resistance at high temperatures are just as applicable for preventing sulphur attack at high temperatures, a problem that is important to the petroleum industry. In such applications, one must consider the heat of formation, the density, the conductivity, and the possibility of solid solutions of the sulphides.

ALBERT M. PORTEYIN

Schaffhausen, Switzerland

# An Eminent Swiss Metallurgist

As a member of Tour Group 1 of the First World Metallurgical Congress, I was so struck with the value of an open interchange of information that I reread the biography of Johann Conrad Fischer, founder of the Swiss engineering and steel founding firm which bears his name. He made several journeys to France and England during his life, was an admiring friend of Michael Faraday (early student of alloy steels) and a metallurgical pioneer. His diaries cite many instances where he picked up valuable ideas from his foreign friends, and was able to reciprocate in kind.

Since the very excellent "Chronology of Iron and Steel" compiled by Prof. Stephen L. Goodale of the University of Pittsburgh contains no reference to Fischer's work, I may be pardoned for citing a few items. It is common knowledge that Benjamin Huntsman invented "crucible cast steel" prior to 1750, wherein cemented (high-carbon) steel bar was melted in clay crucibles. However, practical details of process were kept secret, and there were only three manufacturers in England 50 years later. Johann Conrad Fischer was the first continental to take up the idea, and he probably worked out the details independently. He exhibited "homogeneous cast" steel, worked into tools, at the Berne exposition in 1804. Evidence indicates that he used very small crucibles containing about 20 lb. of metal, six in a single furnace, charcoal fired with hot blast. It is also inferred that his raw material was wrought iron (much cheaper than cemented bar) plus some unknown addition, undoubtedly a carbonaceous substance.

The furnace he used was obviously capable of high temperature (in fact, he once showed Faraday a button of melted platinum), so it was only a short step to melt soft steel—even wrought iron. He even-

#### Correspondence

tually solved the problems connected with sand molds for soft steel castings and made horseshoes and gun lock parts as early as 1840. At the London Exhibition of 1851 he displayed a cast bevel gear.

While British literature and patent records contain references to steel castings in sand molds as far back as 1824, it is certain that the first "commercial" production of steel castings was in Fischer's steel works in Schaffhausen. The exact date cannot be fixed, but was somewhere around 1840.

Johann Conrad Fischer was noted for other things as well — notably, commercial production of nickel steel (called "meteor steel" because meteorites usually contain nickel) which was utilized for coining dies, heavy springs, and other parts where its high hardenability and superior toughness were of advantage. He also transplanted the British-French process of malleable iron into the Teutonic countries.

MAX HUBER Metallurgist George Fischer, Ltd.

## Explosive Nature of Concentrated Nital

CAMBRIDGE, MASS.

The letter of W. R. Meyer, which appeared in the December 1951 issue of *Metal Progress*, calls attention to the importance of safety in the handling of electrolytes for electropolishing of metals. It seems appropriate to publicize the hazard present in the use of another electrolyte.

A violent explosion of approximately one liter of a solution consisting of 1 part nitric acid and 2 parts methyl alcohol occurred in our laboratory recently. The component liquids had been mixed with the usual precautions, followed by cooling. The solution had then been poured into a bottle which previously contained orthophosphoric acid, but which had been cleaned by rinsing. The explosion occurred approximately two hours after the solution had been poured into the bottle, which was left standing quietly for most of this time. Signs that pressure was building up in the bottle, which was closed by a screw cap, were observed barely in time so that injury by fragments of glass was avoided.

Possibly, some trace of orthophos-

phoric acid remained in the bottle and helped to catalyze the explosive reaction. However, nital of high concentration has been known to explode in the absence of recognized catalytic effects while being stored. Although such explosions are probably somewhat less powerful than explosions of perchloric acid electrolytes, they constitute a distinct danger. It should be pointed out that several commonly consulted sources of laboratory information gave the composition of this electrolyte, but failed to mention any danger associated with its use.

The nital electrolyte had been intended for electropolishing muntz metal. It was later found that a solution of 600 cc. of orthophosphoric acid (85%) diluted to one liter with distilled water was an excellent electrolyte for this work.

J. E. REYNOLDS, JR.
Instructor
Department of Metallurgy
Massachusetts Institute of Technology

#### Dogged Metal

**ДЕТВОІТ**, МІСН.

The accompanying photomicrograph should provide convincing proof that even metal can go to the dogs. This dog's head appeared in a sample of Muntz metal (60% Cu, 40% Zn) which was etched with ammonium hydroxide and hydrogen peroxide, 350 ×.

GEORGE L. PARROTT

Metallographer

Michigan Division

Revere Copper and Brass, Inc.





### **Proves Its Stamina in Machinery Gears**

Black-Clawson Company of Hamilton, Ohio, reports several advantages obtained in their production of paper mill and allied equipment by replacing alloy gear castings and forgings with parts made from Ductile Iron.

The gear, illustrated, is typical of these Ductile Iron castings.

Not only has Black-Clawson saved critical materials by using Ductile Iron, but the ease of fabricating contributes to the maintenance of production schedules.

Black-Clawson foundries now produce Ductile Iron in five basic grades for castings that range from less than a pound to more than  $7\frac{1}{2}$  tons in weight. Tensile strengths up to 216,000 p.s.i., and hardness that exceeds 400 BHN, may be attained by heat treating Ductile Iron. This company also successfully welds Ductile Iron.

to steel, to stainless steel, and to itself.

Ductile Iron applications include as-cast and heat treated components for industrial, automotive and agricultural equipment. Also, for railway and other heavy industrial equipment, as well as that used in textile, electrical, marine and other fields too numerous to list.

Counsel and data on Ductile Iron are freely available to help promote intelligent utilization of critical materials. Send us details of your prospective uses, so that we may offer a list of sources from some 100 authorized foundries now producing Ductile Iron under patent licenses. A list of publications on Ductile Iron is available on request.



THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.

APRIL 1952; PAGE 96-A

### S-Curves for Chromium Stainless Steels

Courtesy Metallurgical Department, Republic Steel Corp.

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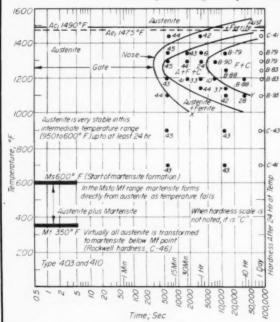
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Actual Analysis: 12.4 Cr, 0.94 Mn, 0.44 Mo, 0.35 S, 0.10 C. M<sub>s</sub>, 625° F.; M<sub>f</sub>, 350° F.

40 30 Min SAMO

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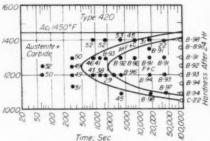
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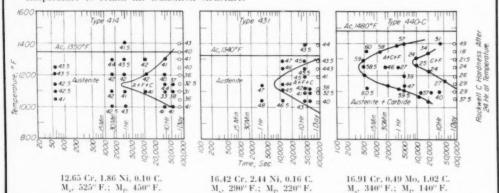
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Actual Analysis: 12.3 Cr, 0.62 Si, 0.098 C. The Mg and Mf temperatures were determined with a quenching dilatometer

Hardnesses noted are for small samples from a typical heat, quenched in salt at indicated temperatures and times, and then quenched to room temperature to retain the transition structure.

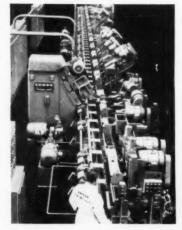
Actual Analysis: 13.0 Cr, 0.42 Mn, 0.10 Mo, 0.013 S, 0.35 C, M<sub>s</sub>, 575° F.; M<sub>f</sub>, 400° F.



Hardnesses decrease with increasing time-attemperature, the minimum hardness generally being reached after 3 hr. Each of these steels has pronounced air-hardening characteristics, and each exhibits an apparently stable region of austenite between 1000° F, and the Ms temperature.

These steels are well suited to heat treatment by martempering. Most satisfactory method for softening Types 414 and 431 is by subcritical annealing at 1275° F.

# The Cross Company increases production, eliminates distortion and scale



... AEROHEAT Heat Treating Compounds
Austemper Spindles and Gears
of Cross Transfer-matic

# THE PARTS

### THE TRANSFER-MATIC

Important in the manufacture of this Cross Transfer-matic for the production of automatic transmission housings is the heat treatment of its spindles and gears.

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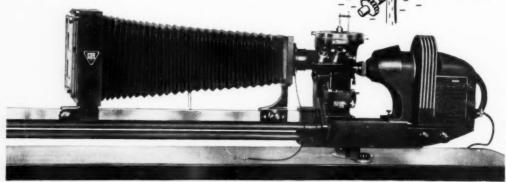
Cyanamid's heat treating compounds include: AEROCARB \* Carburizing Compounds AEROCASE \* Case Hardening Compounds AEROHEAT \* Heat Treating Compounds Spindles and gears are made of A.I.S.I. E-6150 steel. They are brought up to a temperature of 1550°F in AERO-HEAT 1200, quenched at 600°F in AERO-HEAT 300 and aircooled. Finished hardness: approximately Rockwell C45.

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Bausch & Lomb Metallurgical Equipment

### By Thomas J. Dolan, Research Professor of Theoretical and Applied Mechanics

University of Illinois, Urbana

N ARTICLE in the March issue of Metal A Progress discussed ways and means of appraising metals for high-temperature service. It was shown that in the laboratory tests for strength and endurance the investigator makes every effort to maintain steady test conditions. For example, in a creep test, the temperature, load and atmosphere are rigidly constant. In a fatigue test, the temperature, cycle of loading, and atmosphere are constant. While this is necessary if reproducible and comparable results are to be secured, they fall far short of predicting conditions in service, wherein there are almost certain to be large variations in temperature and in nature, cycle, and intensity of stress. Consequently the reported properties of refractory alloys at high temperature are to be accepted with reserve and in the light of as much service experience as obtainable.

The text and illustrations to follow will now discuss some specific alloys and some special tests for severe services at high temperatures.

In addition to high mechanical strength at elevated temperature, it is also desirable that an alloy exhibit (a) good ductility, (b) resistance to erosion, oxidation or chemical attack, (c) high fatigue strength against mechanical or thermal stresses, and (d) adequate stability (the ability to resist prolonged service at elevated temperature without significant deterioration of important mechanical properties).

Prior to World War II, alloys in this field were principally of the nickel-chromium family, and are rather fully described in "Metals Handbook", 1948 edition, p. 549. A wide variety of complex combinations has been studied in the past ten years, based on cobalt, chromium, iron or nickel, together with smaller amounts of molybdenum. tungsten, vanadium, columbium, aluminum, titanium or tantalum to increase hightemperature strength. Most of the available information on these complex materials has been provided by sponsored research during the war (primarily on contracts with National Defense Research Council and National Advisory Committee for Aeronauties). Use of east alloys in preference to forged is based on their superior properties in both creep and stress-to-rupture tests of long duration.

The short-time high-temperature properties of castings, however, are definitely lower than those of the wrought materials.

Wide variations in cross section of most turbine blades and similar equipment are accompanied by variations in grain size, region to region, in either forging or casting, with corresponding variation in ordinary mechanical properties. Little information appears to be available regarding the effect of metallurgical factors such as grain size

### Problems of Metallic Fatigue at High Temperature

on the high-temperature fatigue strength. Toolin and Mochel, in *Proceedings*, American Society for Testing Materials, Vol. 47, 1947, p. 677, indicate that the metallurgical treatment for optimum *fatigue* properties may be somewhat different from that required for optimum *creep* properties. If so, some compromise must be reached in selecting the initial metallurgical treatment and processing methods.

Precision castings often have a coarse grain in comparison with the similar wrought materials; this is sometimes considered desirable for good creep resistance except where single grains occupy the full cross section of highly stressed parts or where wide variations in the modulus of elasticity result. However, Grant found that a certain degree of coarseness of structure should not be exceeded because grain orientation will

\*Professor Dolan's complete paper is entitled "Past Work on the Fatigue of Metals in the High-Temperature Field", and comprises Technical Report No. 17 to Project NR-031-005. Office of Naval Research, U. S. Navy, Contract N6-ori-71, Task Order IV. The study was conducted in the department of theoretical and applied mechanics of the University of Illinois. Acknowledgment is due P. Mathur for assistance in collecting references and to F. Pintak, who aided in preparation of illustrations.

### Static Mechanical Properties

play too large a role, sometimes causing early failure (*Transactions*, American Society for Metals, Vol. 39, 1937, p. 335). In one instance Toolin and Mochel found that fine-grained specimens had better fatigue strength at 1200° F. than another group with coarser grain.

Most of the high-temperature alloys of both the ferritic and austenitic types maintain their strength at elevated temperatures through a continued aging with time, thus being metallurgically unstable in use. Precipitation of complex phases within the alloys may alter the mechanical properties to a marked extent. Losses in ductility or serious embrittlement may occur in certain of the stainless and heat resisting alloy steels: other types may recrystallize and grow large grains on prolonged heating. Ductility and notch impact resistance of austenitic Cr-Ni-Fe alloys may be markedly decreased by prolonged exposure to elevated temperatures (as indicated by Payson and Savage, Transactions, American Society for Metals, 1947, p. 404), but it is not known what effect these changes may have on the fatigue resistance. Therefore, any data presented for mechanical properties are applicable only to the particular heats processed, heat treatments utilized, and duration of the tests.

The danger exists, of course, that "overaging"—with consequent loss of fatigue strength or other desired properties—may occur after considerable time at high temperature. Since the severity of the harmful effect and the structural changes are a function of the total time in service, this consideration may not be particularly important in those units designed for only a few hundred hours' service, but it is of primary importance where the material is expected to perform continuously for many years.

It is usually assumed that the cyclic stress or previous stress history does not affect the metallurgical character of the material or its properties in a manner different from that which would occur from static stress of similar magnitude. Probably these assumptions are unjustified; cyclic stressing may accelerate solid-state transformations or cause slip or other forms of lattice distortions different from those caused by static loads. "Damping" studies on aluminum alloys indicate that vibratory stress sufficiently prolonged may produce changes in

metallurgical conditions that are normally associated with increased temperature, aging, and annealing. Under sustained static loading at elevated temperatures, changes in hardness have been observed in widely used precipitation hardening alloys.

Based on a study of approximately 100 experimental alloys, Freeman, Reynolds, and White ("High-Temperature Alloys Developed for Aircraft Turbosuperchargers and Gas Turbines", Symposium on Materials for Gas Turbines, American Society for Testing Materials, 1946) concluded that a systematic relationship between chemical composition and static mechanical properties does not exist, primarily because heat treatment and fabrication strongly influence the properties. Some of the fundamental reasons for variations in properties at high temperatures are not understood; strain hardening from cold work, and size and distribution of complex precipitated compounds appear to be controlling factors. Prior heat treatment may influence the static properties of wrought alloys at 1700 and 1800° F. It may be inferred from these observations on static tests that a similar (or even greater) variability may be expected in fatigue strength as a result of heat treatment, processing and fabrication procedure.

When tested at temperatures ranging from 400 to 800° F., aluminum alloys are subjected to combined creep and fatigue somewhat analogous to the conditions in alloy steels and high-temperature alloys above 1000° F. Jackson, Cross, and Berry found that the tensile strengths of aluminum alloys 18S-T. 32S-T. and 24S-T decreased above 350° F. as the testing temperature increased; the tensile strength of each alloy was also affected by the length of time the specimen was held at temperature before beginning the test. As a generalization, it might be estimated that the static tensile and yield strengths decrease as a function of the logarithm of the time at temperature. Consequently, these investigators concluded that the fatigue cycle frequency is an important factor. (See N.A.C.A. Technical Note No. 1469, March 1949.)

Perhaps the most complete and systematic survey of the fatigue properties of a wide variety of high-temperature alloys is contained in the above-cited work of Toolin and Mochel. They present more than 70 fatigue curves obtained at 1200 and 1500° F, on various alloys tested in reversed bending

with zero mean stress. The specimen was a fixed cantilever beam, vibrated at a frequency of 120 cycles per sec. (roughly 10 million cycles in 24 hr.) in a machine of the magnetic resonant vibratory type. Test specimens were of two sizes—either 0.550 or 0.333 in. in critical diameter. The smaller specimen was utilized mainly for precision cast specimens, which were tested with sand-blasted as-cast surfaces; all others were polished.

The following data are scaled from S-N diagrams of Ni-Cr-Fe alloys tested at 1200° F. in the above manner:

	STRESS FO	R FAILURE
MATERIAL.	106 CYCLES	108 CYCLES
16-25-6		46,000
Hoskins 502	44,000	39,000
GT-45	43,000	39,000
Gamma columbium	40,000	33,000
25-20	38,000	29,000
25-12	32,000	23,000

Though most of the curves are relatively flat, they trend toward a continuing downward slope even after 100 million cycles of stress. Hence it is important to state the number of cycles for which a high-temperature fatigue strength is given.

Similar characteristics are shown by the S-N diagrams in Fig. 1 for precision-cast specimens of several alloys tested at 1500° F. Some of the specimens aged during the test and increased in strength with time (and number of cycles); the endurance curves therefore were probably much flatter than if the materials had been stable at the test temperatures.

Toolin and Mochel found that for any specific alloy group, those having higher before-test hardness generally showed superior endurance properties. However, because of the instability of the as-cast specimens during a test, the before-test hardness of these alloys had less significance. Fatigue strength varied considerably between the materials in each alloy group, and of course between the alloys in different groups. Other factors besides chemical composition exercised a considerable effect on the fatigue characteristics at 1200 to 1500° F. For example, after an optimum treatment for high creep strength, one alloy showed a fatigue strength of 52,000 psi.; with a modified heat treatment, it was better than 80,000 psi.

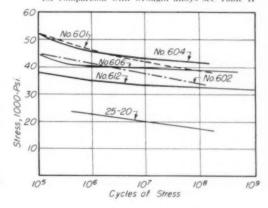
Tables I and II show data for the alloys exhibiting the highest fatigue strength at 100 million cycles of stress at 1200 and 1500° F. respectively. These values show vast

improvement over a 0.17% carbon steel reported by Moore and Alleman, which had a fatigue strength of 8000 psi, for 10 million cycles at 1200° F. They are also considerably above the results reported by Cross in 1934 on low-carbon and high-carbon 18-8 steel, ranging from 20,000 and 23,000 psi, for cast 18-8 to 30,000 and 32,000 psi, for the rolled alloy at 1200° F.

For several of the alloys tested by Toolin and Mochel the wrought form gave the higher fatigue strength. While there were only two cast metals in the first 12 at 1200° F. (Table 1), five of them were listed in the highest 12 at 1500° F.

In general, the wrought alloys exhibit somewhat superior fatigue resistance, whereas easting may often leave the metal in a metallurgical condition more resistant to creep. In the high-temperature ranges for which an interaction of creep and fatigue occurs, it becomes difficult to predict which of these two will limit the strength. At the excessive temperatures where creep becomes the predominant action, the cast alloys may prove to be superior to the same metals in wrought form, but at lower temperatures (say in the region of 1000 to 1200° F. for the special alloys mentioned) it seems likely that the metallurgical condition and surface preparation should be designed to give optimum fatigue life, particularly if cyclic stresses of high frequency are to be resisted. On the other hand, if the fluctuations of stress are

Fig. 1—S-N Curves for Some Precision-Cast Alloys at 1500°F. According to Toolin and Mochel. For code numbers and compositions see Table I; for comparison with wrought alloys see Table II



### High-Temperature Fatigue Data

not a major consideration, an entirely different metallurgical processing might be desirable to promote optimum creep strength or resistance to static stressrupture.

Fatigue strength of many of these alloys exceeds the static tension stress that would be expected to produce rupture in 1000 hr. at the same temperatures. This is also in line with the observation of Moore on carbon steel and of Cross on 18-8 that "the S-N curves indicate that

a design based upon allowable deformation within the life of the material in service will not result in a fatigue failure". This statement is, of course, based on the assumption that the total deformation (primarily creep) would normally be relatively small.

One might predict that the creep taking place in a fatigue test would be somewhat more pronounced when the stress cycle varies from zero to a maximum in an axial load test than in reversed bending or completely reversed cycles of axial loading. The mean stress existing in the "zero to maximum" stress cycle is one half of the maximum, whereas the mean stress in reversed bending is nominally zero. Therefore, the effect of creep should be more significant with higher mean stress.

At high temperatures (and correspondingly large creep rates) the damage produced by a steady stress may exceed the progressive damage from a superimposed cyclic stress. As the temperature is raised, the relation between stress amplitude and number of repetitions sustained to fracture is gradually transformed into a relation between the mean stress and the time to fracture. Therefore, fatigue design at exceedingly high temperatures may become primarily a design for creep; the effect of the alternation can be disregarded if the mean stress is relatively high. At moderately high temperatures (for which the creep rate is small and the corresponding static creep-to-rupture stress is relatively high) longer times would be required for the damaging effects of creep to be manifested. Under these conditions, and particularly for conditions in which the mean stress is zero, the progressive damage associated with the repeated

Table II — Alloys in Order of Fatigue Strength at 1500° F.

	4.	FATIGUE STRENGTH				
NUMBER	NAME	1500° F.	1200° F.			
102	S-816	47,000	70,000			
104	Vitallium, rolled	44,000	63,000			
101	Midvale GTA	42,000	71,000			
604	Vitallium, cast	41,000	44,000			
301	A.H. Inconel "X"	40,000	65,000			
606	61, Stellite 23, cast	38,000	44,000			
309	K-42-B	38,000	52,000			
601	6059, cast	38,000	63,000			
202	Hastelloy B	35,000	66,000*			
602	X40, cast	34,000	56,000			
109	N-155, low carbon	33,000	61,000*			
612	S-816, cast	32,000				

\*This test on an alloy of somewhat different composition. See Table 1.

Table I - Highest Alloys Tested, in Order of Fatigue Strength† at 1200° F.

No.	Name	С	MN	Si	Cn	Ni	Мо	Co	M.	Св	Ti	AL	FE	FATIGUE STRENGTH
101	Midvale GTA‡	0.19	0.65	0.64	19.91	32.10		30.05	5.41	4.00			Bal.	71,000
102	S-816	0.36	0.72	0.19	18.40	20.23	3.72	45.63	4.23	3.04			Bal.	70,000
612	S-816, cast	0.38	0.82	0.25	18.87	19.70	4.04	45.64	4.71	3.43			Bal.	
201	Hastelloy B	0.12	1.20	0.52	0.27	60.83	27.10						9.96	66,000
202	Hastelloy B	0.04	0.11	0.26		64.42	29,37		****				4.20	
301	A.H. Inconel "X"#	0.03	0.50	0.27	14.52	73.31				1.17	2.36	0.67	7.06	65,000
304	K-42-B	0.05*	0.7	0.59	18*	42*		22*	****		2.17	0.48		63,000
1404	Vitallium, rolled	0.22	0.65	0.53	27.42	2.28	5.53	62.20	****				0.70	63,000
601	6059, cast	0.37		0.52	25.8	34.8	4.72	33.5					0.65	63,000
105	N-155‡	0.15	1.46	0.42	20.84	20.58	3.18	20.48	2.26	1.06			Bal.	61,000
109	N-155, low carbont	0.06*			20*	20*	3*	20*	2*	1 *			Bal.	218448
602	X40, cast	0.54	1.02	0.61	25,46	10.27	0.21	50.28	6.74					56,000
106	S-590	0.17	1.35	0.82	19.40	19.07	4.03	19.26	4.00	3.98			Bal.	55,000
308	Refractaloy 26	0.05	0.65	0.72	17.9	37★	2.80	20*			2.60	0.30	Bal.	52,000
309	K-42-B	0.05		0.60	18*	42*		22*			2.45	0.37	Bal.	52,000
108	Timken No. 2	0.14	1.56	0.92	17.64	27.65	9.52	35.60					Bal.	50,000
606	61, Stellite 23, cast	0.45*		1000	28*	2*		64*	6*				****	44,000
604	Vitallium, cast	0.25 ★			28*	2*	6*	64*						44,000

\*Type analysis.

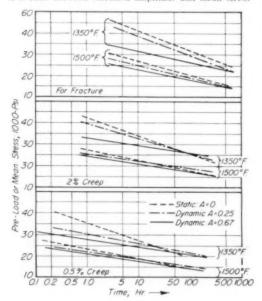
†Fatigue strength at 100,000,000 cycles, psi. ‡Additional elements: 0.15% N in Midvale GTA; 0.02% Cu in Inconel "X"; 0.15% N in N-155. Data from "High-Temperature Fatigue Strength of Several Gas Turbine Alloys", by R. R. Toolin and N. L. Mochel, *Proceedings*, American Society for Testing Materials, Vol. 47, 1947, p. 677. loading (the cycle effect) becomes more significant.

Lazan, in "Dynamic Creep and Rupture Properties of Temperature-Resistant Materials Under Tensile Fatigue Stress" (Proceedings, American Society for Testing Materials, 1949, p. 757), presents definite information regarding such superimposed effects at temperatures of 1350 and 1500° F. He tested alloys N-155, S-816, Vitallium, and 19-9DL for creep, time-to-rupture, and unidirectional tension on which was superimposed an alternating cyclic stress (at a frequency of 3600 cycles per min, whose amplitude was either one quarter or two thirds the mean stress).

Typical results are shown in Fig. 2. At 1500° F, the superposition of an alternating stress did not significantly affect the time to rupture—the three lines are not too divergent. At 1350° F, however, the cyclic stress had a more pronounced influence in decreasing the total life of a specimen, particularly for tests of relatively short duration (when the stresses were high).

The allowable creep or rupture stresses for 200-hr, life were not appreciably affected by superposition of alternating stresses; the

Fig. 2 — Effect of Superimposing Alternating Loads of 25% or 67% of Mean Stress on Time to Rupture of N-155 at 1350 and 1500% F. (Lazan, *Proceedings*, A.S.T.M.) A is ratio between vibration amplitude and mean stress



### Effect of Superimposed Stress

lines in Fig. 2 practically intersect at that time. An exception is rupture at 1350° F. It occurred at 200 hr. under a steady mean tensile stress of about 29,000 psi., but the allowable mean stress was reduced to 25,000 psi. when an alternating stress of as much as 17,000 psi. was superimposed.

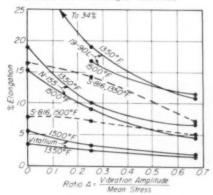
#### RELATIVE DUCTILITY RATINGS

However, as indicated in Fig. 3, the relative ductility rating in a static tensile test is quite different from that in cyclic loading. There seems to be a tendency for elongation to decrease as the ratio of the alternating stress to the mean stress is increased. Since the decrease in elongation varied from 29 to 63% of the static value for the different materials, the ductility under static loading may be significantly different from the ductility under dynamic loading.

For purposes of comparison, Lazan defined a "mean dynamic to static stress equivalence ratio E" as indicating the ratio of the allowable mean stress S<sub>m</sub> under dy-

namic loading to the equivalent static stress S, which caused the same creep or rupture behavior. If E is larger than unity, it indicates that the additional cyclic stress increased the life or reduced the creep; if E is smaller than unity, an accelerated creep or rupture was caused by the cyclic stress.

Fig. 3 — Effect of Superimposing Alternating Loads on Mean Stress on Elongation of Specimen at Fracture, (Lazan, *Proceedings*, A.S.T.M.)



### Tests on Aluminum and Cast Iron

Figure 4 shows average values for the several alloys tested of this ratio E for rupture and for 0.5 or 2% creep at the end of various time intervals. The solid lines show data obtained using an alternating stress  $S_a = 0.67 S_m$  and the dashed lines for  $S_a =$  $0.25 \, S_{\mathrm{m}}$ . It is interesting to note that all creep and rupture data at 1500° F. for  $S_n = S_m = 0.25$  show average E larger than unity; that indicates an important fact that the superposition of an alternating stress equal to one quarter the mean stress produced less rapid damage than would have occurred if the mean stress were applied as a steady load. However, for larger amplitudes of alternating stress  $(S_n + S_m = 0.67)$ or for the lower temperature (1350° F.) the cyclic stress accelerated the creep and rupture (values of E were less than 1.0).

Lazan observes that "the importance of cyclic stress as an accelerator of creep and rupture decreases with increasing temperatures and, in fact, at sufficiently high temperatures, cyclic stress may even decelerate creep and rupture". Data obtained by Mond Nickel Co. indicate that cyclic stress may actually strengthen the material against creep when the maximum cyclic stress is in excess of the rupture stress for that particular temperature.

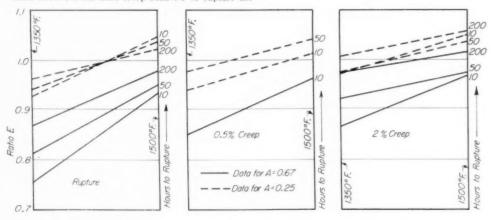
At 1350° F., however, the superposition of 67% alternating stress reduced the allow-

able static stress in Lazan's tests by as much as 25%. In general, the shorter the hours to failure (high mean stress), the greater the reduction of allowable stress caused by the superposition of alternating stress. Thus, in apparatus designed for short service at relatively high stress levels, the acceleration of creep by repeated stressing at high temperatures may reduce the allowable stresses substantially below those which would be indicated solely by rupture considerations.

Tests made by Manjoine on 14S-T aluminum alloy at 400° F. are shown in Fig. 5. An alternating stress whose amplitude was 10% of the mean stress was applied at a frequency of 20 cycles per sec. These data indicate that up to about 200 hr. the time to rupture under this type of pulsating load (upper solid line) was shorter than for a constant load equal to the mean stress (dashed lines), but the reverse was true for tests at low stress levels (the lines cross at 200 hr.), so that the allowable mean stress for rupture in 300 hr. was actually increased by adding an alternating stress. The same inversion was observed in creep rates above and below  $4 \times 10^{-5}$  per hr. These results appear to represent peculiar trends similar to those noted by Lazan on heat resistant alloys at 1350 and 1500° F.

While cast iron is not generally used for stress-carrying members operating at high temperature, interesting questions are raised by the data obtained by Collins. In the 1948 *Proceedings* of the American Society for Testing Materials (p. 696) he gives endurance limits of an austenitic cast iron as shown on the next page.

Fig. 4 — Lazan's Diagram Showing That Superimposed Alternating Loads Increase Resistance to Deformation When E Is Greater Than Unity. E is ratio of allowable mean stress under dynamic loading to the equivalent static stress for the same creep behavior or rupture life



TEST	UNNOTCHED	NOTCHED
TEMPERATURE	SPECIMEN	SPECIMEN
70° F.	14,000	12,600
400	17,000	13,200
700	14,000	14,500
900	10,000	13,300
1160	12 000	12 000

The stress in the notched specimens was figured on the net area. The austenitic cast iron varied little in fatigue strength in reversed bending (at 2500 cycles per min.) from 70 to 1160° F. Of even greater importance is the fact that specimens with a small hole transverse to the axis of the cylindrical specimen (diameter one tenth the diameter of the specimen) had fatigue strengths as great as those of the unnotched specimens. In other words, the presence of a serious stress raiser did not weaken the cast iron. though data indicate that this would have reduced the fatigue strength of steel by at least a factor of two. If high-temperature alloys are found to be notch-sensitive at working temperatures, their fatigue strengths may not be greatly superior to this cast iron.

#### DAMPING CAPACITIES

Damping capacities of the high-temperature alloys are too nearly alike for the differences to be of practical significance, and apparently none of the present-day hightemperature alloys seem to exhibit high

damping capacity. Therefore, alloys having fairly high fatigue strength have usually been selected. Some designers try to add to the natural damping characteristics by mechanical assembly of components rather than by welding. The extremely high inherent damping capacity of some material such as cast iron would prove highly beneficial in minimizing the stress range for which the blade must be designed.

In evaluating past work in the field of high-temperature fatigue, or in planning a research program for future study, the following factors should be given careful consideration:

1. The instability of (and effect of changes in) the metallurgical structure with elapsed time at the elevated temperature.

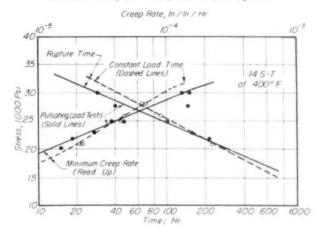
### Service Conditions Defined

- The influence of erosion, surface oxidation, and chemical changes induced by the environment.
- The relative influence of time (for creep to accumulate) as compared with the frequency with which the repeated stresses are applied.
- Modifications in the behavior caused by the superposition of a mean or steady stress, which tends to accelerate creep but which may not markedly influence the fatigue characteristics.

To obtain fundamental data on the combinations of circumstances that lead to failure in high-temperature fatigue, the interactions of the above four parameters (which define the service condition) must be quantitatively evaluated. The parts which chemical and metallurgical change play in altering the properties during sustained exposure to high temperatures have not been fully recognized as having a major effect on laboratory test data. As an illustration, let us review the effect of pulsating loads on time-to-fracture when the temperature is high enough to cause appreciable creep.

Limited tests made by Greenwood and Cole (reported in *Metallurgia*, Vol. 39, 1949, p. 121) indicate that the creep rate of a lead alloy was markedly increased by the presence of a superimposed vibration. Manjoine's

Fig. 5—Creep and Rupture Tests of 14S-T Aluminum Alloy Disks at 400° F. Under Constant Load (Dashed Lines) and With an Alternating Load 10% as Large Superimposed. (Manjoine, *Proceedings*, American Society for Testing Materials, 1949, p. 788)



### Fundamental Information Needed

tests on aluminum alloys and Lazan's on high-temperature alloys cited in Fig. 2 to 5 also present convincing evidence that the over-all creep may be accelerated by a superimposed alternating load for certain combinations of temperature and mean stress. Thus, in some instances the presence of fluctuating load may limit the life of a member not only by the possibility of fatigue fracture but also by the indirect process of stimulating excessive creep. Nevertheless, for other sets of conditions (involving an increase of temperature in Lazan's tests or for the lower stress levels in Manjoine's tests) there may be a beneficial effect (decreased creep and longer time to fracture).

The reason for this perplexing phenomenon is obscure, but it might be explained by the probable structural changes. At high temperatures an accelerated precipitation of hardening constituents may be catalyzed by the alternating stress, and this strengthening might be accompanied by a beneficial relaxation of the microstresses developed around the precipitated constituents. At lower temperatures both of these beneficial actions would progress at a low rate per cyele, and would be counteracted by slip and structural damage (on the crystalline scale) caused by the stress repetition. At somewhat lower stress levels, however, for which the time of test is greatly increased (and for which the fatigue damage progresses at a very low rate per cycle) the beneficial effects may again have sufficient time to improve the strength of the material during the test (or to prolong its life).

A strong need exists for fundamental information on the nature of the phenomena limiting the life of a metal in high-temperature fatigue; such information should eventually lead to more accurate methods for predicting the useful service life of specific components. Several important questions (to which there is at present no definite answer) might be formulated as follows:

1. Creep may or may not be accompanied by plastic flow (that is, slip within the crystals). Freudenthal (in "Types of Inelasticity of Structural Materials and Procedures of Design", Institute of Aeronautical Sciences, Preprint No. 258, January 1950) suggests that peak stresses are relieved by plastic flow but are not influenced by purely viscous creep. On the other hand, concen-

trations of strain around localized regions of abrupt change in section are not relieved by flow. Is it stress or strain that is of prime importance, and how is the criterion of failure governed by the interaction of creep and plastic flow?

2. Elevated temperatures increase the mobility or accelerate the place change of atoms, which should facilitate greater deformation prior to fracture. However, the breakup of crystal grains by slip is opposed by the tendency to re-form into a limiting minimum stable grain size, so that recrystallization or grain growth may result (particularly after plastic deformation). Other metallurgical changes such as precipitation, aging, and phase changes might be accelerated by repeated stressing. Does this instability and continual change of structure lead to marked modifications in fracture characteristics? Are the flow and fracture criteria functions of (or altered by) the load cycle. or are they primarily dependent on time and temperature?

3. For steels at room temperature, slip is a discontinuous process governed mainly by the resolved (or critical) shear stress level. At elevated temperatures, however, relaxation and recovery may allow further slip to proceed at the same stress level. The disordered material within slip bands and along the crystalline boundaries is very sensitive in its behavior to the effects of time and temperature. Does the fact that hot metals do not exhibit a definite endurance limit relate itself to the inability of the material to strain harden and resist further inelastic action?

4. To what extent do surface effects such as erosion, oxidation, chemical attack and film formation serve to initiate or nucleate a fatigue fracture at elevated temperatures?

These are only a few of the questions stemming from a lack of basic information.

In summary, the author can only reemphasize the need for further research and
carefully planned experimental programs
which seek an answer to some of these
questions or which would serve to clarify
the rather complex interactions occurring
in high-temperature service. Only after
extensive new contributions are made to
our present sketchy understanding of hightemperature fatigue can the significance of
present data be interpreted and adequate design procedures be evolved.

### ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street. New York 17. N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario.

### How NITROGEN Refines Grain Size... Produces Harder, Stronger, Tougher Chromium Steels

When nitrogen is added to high-chromium steel, it greatly refines the grain size of the metal and materially increases its strength, toughness, hardness, and wear resistance without sacrificing ductility or reducing corrosion resistance. For these reasons, nitrogen-bearing chromium steels are well suited for cutlery, turbine blades, and various machinery parts that are subject to extreme wear.

#### Added to Steel In Ferrochrome

Nitrogen is usually added to chromium steels in the form of nitrogen-bearing ferrochrome containing 0.75 per cent and up of nitrogen, 70 per cent chromium, and a maximum of 0.10 per cent carbon. Depending upon the chromium content of the steel, which can range between 12 and 30 per cent, the nitrogen content may vary between 0.06 and 0.20 per cent. The amount of nitrogen added to high-chromium steels should be 1 part of nitrogen to between 100 and 200 parts of chromium, depending upon the chromium content of the steel.

Nitrogen-bearing ferrochrome is added to the furnace in the same manner as ordinary ferrochrome. Nitrogen recovery will average about 90 per cent.

#### **Improves Cutlery Steel**

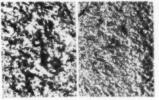
Cutlery steels and other martensitic stainless steels, such as the 12 to 14 per cent chromium low-carbon steels that are used for turbine blades, are hardenable by heat-treatment. Hardenability and strength increase with the carbon content. And, since nitrogen is a more powerful austenite-former than carbon, it is sometimes used as a substitute for part of the carbon, or as a supplement to the carbon, to increase the strength and hardenability of these steels.

Nitrogen has distinct advantages over carbon for this purpose because ductility, toughness, and corrosion resistance are retained when nitrogen is added to steel. It increases the hardness of cutlery steels without detrimentally affecting toughness or corrosion resistance. The effect of small additions of nitrogen in increasing the hardness of cutlery steels is shown in the table below.

#### Reduces Grain Growth During Hot-Working

The ferritic high-chromium stainless steels to which nitrogen is added have a finer grain size than ferritic steels without nitrogen, which are comparatively coarse-grained. These include the 16 to 18 per cent chromium wrought steels, high-chromium steels containing small percentages of nickel, and both the cast and wrought 20 to 30 per cent chromium steels. The function of nitrogen when added to the ferritic high-chromium steels is to preserve a fine grain size.

The nitrogen-bearing, high-chromium wrought steels are more readily rolled and forged than comparable steels containing no nitrogen, because grain growth is in-



Note the extent to which nitrogen relines the grain size of those specimens containing about 27 per cent chromium and 0.35 per cent carbon. The specimen at the left contains 0.05 per cent nitrogen; the one at the right, 0.30 per cent nitrogen.

hibited during hot-working operations. Greater yields are therefore obtained in rolling and fabricating. Also, strength and toughness are increased as a result of the grain refinement caused by the nitrogen addition.

#### Greater Strength for Austenitic Steels

Small percentages of nitrogen will increase the yield point and tensile strength of the austenitic chromium-nickel steels. These include the well-known 18 per cent chromium, 8 per cent nickel steels, and also the 25 per cent chromium, 12 per cent nickel steels. The improvement in strength is gained at practically no sacrifice of workability. Furthermore, nitrogen promotes the formation of austenite.

#### Metallurgical Service Available

ELECTROMET nitrogen - bearing ferrochrome is furnished in the following standard analysis:

Chromium	67 to 71 %
Carbon	0.10% max.
Silicon	0.30 to 1.00%
Nitrogen	0.75% apprex., er
	bloken If desired

It is produced in lump sizes of 25 lb. by 8 mesh, or 15 lb. by 8 mesh; also, in a crushed size of 2 in. by down.

If you would like additional information about the production of nitrogen-bearing steels, ask to have one of our metallurgists call, or ask for the booklet, "Nitrogen In Chromium Alloy Steels," Write to the address given above or to the Electromet office nearest to you. Offices are in Birmingham, Chicago, Cleveland, Detroit, Los Angeles, New York and San Francisco. In Canada: Welland, Ontario.

The term "Electromet" is a registered trademark of Union Carbide and Carbon Corporation

% Cr.	% c	% Si	% Mn	% Me	% N	Rockwell C Hardness	Brinell Hardness Numbers (by conversion)
13.15	0.12	0.30	0.38		0.03	41	387
13.25	0.13	0.29	0.42		0.10	48	460
13.36	0.23	0.28	0.40		0.03	46	437
13.27	0.21	0.34	0.32		0.08	51	496
12.70	0.32	0.30	0.37		0.04	50	484
13.41	0.35	0.31	0.41		0.11	56	560
17.37	0.41	0.32	0.41	0.75	0.036	41	382
17.25	0.44	0.30	0.42	0.75	0.09	41 53	522
17.30	0.66	0.29	0.38		0.03	51 55	496
17.08	0.60	0.31	0.40		0.11	5.5	547
17.26	0.80	0.28	0.39	0.76	0.032	52	509
17.25	0.80	0.27	0.45	0.74	0.09	57	573

"Steels eil-quenched from 950°C. Hald 5 hr. at 200°C. and air-cooled.

### Personal Mention\_



William H. White

WILLIAM H. WHITE . retiring manager of toolsteel sales for the Detroit district of Allegheny Ludlum Steel Corp., began his working career as a machinist, later becoming tool and die maker before entering sales work in the toolsteel industry. He joined the former Atlas Steel Co. as manager of sales of the Cleveland district in 1921. a position which he retained during a series of mergers which absorbed Atlas into Allegheny Ludlum. In 1942 Mr. White went to Atlas Steels Ltd., Welland, Ont., as director of sales. This company was operated by the British government and worked on war materials. In 1946 Mr. White rejoined Allegheny Ludlum as district manager of toolsteel sales, the position from which he has now retired. He has been prominent in various technical societies for many years. He is a past president of the Cleveland Chapter of the American Society for Metals and is a member of the Detroit Chapter at the present time. He is also a member of the Detroit Chapters of the American Society of Tool Engineers and the Society of Automotive Engineers.

S. T. Jazwinski . formerly with the Ford Motor Co., Dearborn, Mich., is now chief research metallurgist with the Central Iron and Steel Co., Harrisburg, Pa.



William E. Ruder

WILLIAM E. RUDER , an authority on permanent magnets and magnetic materials, has retired from the research laboratory of the General Electric Co., Schenectady, N. Y., after more than 44 years service. Although one of the early pioneers in metallurgy in the United States, his most important work has been concerned with magnetic materials. His early work in Alnico, an alloy of aluminum, nickel, cobalt and iron, resulted in permanent magnets far more powerful than those previously made of carbon steel. He was also responsible for development of the so-called "soft" magnetic steels which hold a minimum of permanent magnetism. Mr. Ruder also originated the commercially important "calorizing" process for coating iron and other metals with aluminum. This process, introduced in 1912, is widely used to prevent scaling due to oxidation of metal surfaces. After serving as head of the laboratory's metallurgy division for 12 years. in 1950 Mr. Ruder was named manager of the then newly organized metallurgy research department. From 1933 to 1950 he was a director of the Allegheny Ludlum Steel Corp., Pittsburgh, one of the first companies to manufacture the special steels which he developed for transformers. During World War II he was consultant for the

metallurgy division of the War Production Board and recently was named consultant to the Metallurgical Advisory Board Committee of the National Academy of Sciences. This board advises the armed forces and government agencies on metallurgy problems. Mr. Buder is a member of the American Institute of Mining and Metallurgical Engineers, the American Society for Advancement of Science and the American Ordnance Association. He has been particularly active in the American Iron and Steel Institute.

L. W. Prestin that has been elected vice-president of Sunbeam Corp., Chicago, in charge of the industrial furnace division.

Henry A. Mullen (2), manager of the resistance welding division of Ampco Metal, Inc., Milwaukee, has recently been appointed a member of the Advisory Committee of the Resistance Welder Electrode Manufacturers Industry which works in conjunction with the National Production Authority.

A. J. McCullough has been appointed to the newly created post of regional industrial manager of the Brown Instrument Division, Minneapolis-Honeywell Regulator Co., Cleveland.

A. S. Kasper (a) has been promoted from research metallurgist to staff engineer for the Houdaille-Hershey Corp., Detroit.

David F. Greenawalt (\*) has recently taken a position as a metallurgical engineer with Rich Manufacturing Corp., Battle Creek, Mich.

Robert M. Bracy , a recent graduate of the University of Kansas, is now with Black, Sivalls & Bryson, Inc., Kansas City. He is metallurgical assistant to Robert T. Howard , chief metallurgist.

Harvey B. Nudelman (3), who recently graduated from the University of Illinois, has been appointed a research assis'ant in the metals department at Armour Research Foundation of Illinois Institute of Technology, Chicago

James M. Warfield (a) is employed by the Caterpillar Tractor Co., Peoria, Ill., where he is working in the metallurgical laboratory.

### **BUSINESS IN MOTION**

### To our Colleagues in American Business ...

Substitution of materials is of considerable concern to many manufacturers these days. Never before have we seen so much interest in the subject. However, it is by no means new to Revere, which has always held to the principle of recommending the metal that will best serve the customer. Thus, we have often suggested switching from one metal or alloy to another, with the object of lowering costs, increasing production, improving service, or all three.

When based on a detailed study of all the factors involved, substitution at times can be extremely

valuable. In fact, the everincreasing quality and service to be found in American products is due in part to the continued search for better materials, and their adoption when found. Better materials, better design, finer workmanship—these are part of American progress.

But there are instances, of course, when no practical substitute can be found, when only one material offers just

the right combination of good qualities required for a given application. Take the automobile radiator. This has always been made of copper, because copper is the one and thus far only metal that perfectly meets all the requirements of manufacture and service. To make a radiator, very thin copper sheet and strip must be crimped, bent and otherwise formed. Copper's easy workability makes it ideal from the manufacturing standpoint. After assembly, the radiator is cleaned, and made water-tight by dipping in a bath of hot solder. Copper is exceptionally easy to solder. When in service on a car, truck or bus, the radiator must not rust, and must resist

corrosion by water and anti-freeze. Copper is notable for its resistance to corrosion in such use. The radiator must also cool the water by radiating its heat into the air stream; copper has the highest heat conductivity of all commercial metals. A copper radiator thus is the most efficient and durable. It should outlast the car unless accidentally damaged, and when the injury is not so great as to make replacement necessary, the nearest shop can make repairs easily.

Recently it has been suggested that automotive

radiators should be made of aluminum. However, both copper and aluminum are temporarily in short supply, and therefore to substitute one for the other does not appear to be practical. Beyond that, we do not believe —based upon experience to date—that aluminum's qualities, fine though they are, necessarily make it suitable for automotive radiators. In addition, the difficulties of

retooling in the factory and repairs in the field must be considered. Revere fabricates both copper and aluminum, and we have reason to believe that our impartial advice to stay with copper for automotive radiators is concurred in by radiator manufacturers.

When you are tempted to substitute one material for another in your product, no matter what it may be, make certain you obtain all the facts as to costs, production, service. Your suppliers will be glad to collaborate with you in studying the effects of a proposed change. We suggest you take full advantage of their knowledge and experience,



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### **Personals**

Marvin L. Nelson . formerly chief engineer at Solar's Grand Avenue Works in Des Moines, Iowa, has been appointed works manager of Solar Aircraft Co.'s new Wakonda Works, Des Moines.

R. M. Woodside has been promoted to district industrial manager of the Brown Instrument Division of Minneapolis-Honeywell Regulator Co., Cleveland. Raymond J. Zale & has resigned from his position as a special representative for Darwin & Milner, Inc., Cleveland, to accept a position as a sales metallurgist with Firth Sterling Steel & Carbide Corp., Pittsburgh.

Rod Schrivener 3. after five years of sales engineering work with Kaiser Aluminum and Chemical Sales Inc., Chicago, has been promoted to manager of the market research section in the company's New York Aluminum Development Division.

\*HACK SAWING MACHINES

\*BAND SAWING MACHINES

\*BAND SAW BLADES

\*HACK SAW BLADES

William F. Cassedy, Jr., (a) is now president of Aircraft Radio Corp., Boonton, N. J.

Bruce A. Hainsworth (3), formerly with the H. K. Ferguson Co., Cleveland District, is now director of engineering for E. R. Squibb & Sons, New Brunswick, N. J.

H. Scott Bandy (\$) has been appointed quality control manager of Chase Aircraft Co., Inc., West Trenton, N. J.

Richard M. Hedstrom (a), a recent graduate of the South Dakota School of Mines and Technology, has accepted a position with the Caterpillar Tractor Co., Peoria, Ill.

Adolph J. Lena s is now research metallurgist in the research laboratory of the Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Philip C. Miller (2), who recently graduated from Rensselaer Polytechnic Institute, is now research metallurgist at the Babcock & Wilcox Research and Development Center, Alliance, Ohio.

William J. Fretague (2) recently joined the staff of the metallurgy division of Oak Ridge National Laboratory. He is a former graduate student and research fellow of the department of metallurgy, University of Notre Dame.

William Gibb ( is now chief inspector of the Atlas Foundry & Machine Co., Tacoma, Wash.

Donald T. Surprenant has accepted a position as research and development engineer at the metallurgical laboratory of the Dow Chemical Co., Midland, Mich.

Jean G. Louvier (a), formerly with the Western Cartridge Co., East Alton, Ill., is now a metallurgist with the Mueller Brass Co., Port Huron, Mich.

R. T. Myer thas been transferred to the Massena (N. Y.) Fabricating Works by the Aluminum Co. of America. He was formerly chief metallurgist at the New Kensington Works and will occupy the same position at his new location.

Jay E. Fowler (4) is now employed as plant metallurgist at Michigan Standard Alloys, Inc., Benton Harbor, Mich.

A. C. Paulson has been appointed manager of the St. Paul branch of the Crucible Steel Co. He was formerly a district representative in Bockford, Ill.

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While it is true there are several builders of hack sawing machines, only MARVEL builds 80TH hack saws and band sawing. The fact is that MARVEL manufactures 35 models of 10 basic types of metal sawing machines which include the world's festest eutomatic production saw, the world's largest sjant hydraulic hack saws, the world's most versatile band was and the most widely used small bloops saws.

With intimate and broad field experience in all types of metal cutting-off equipment and 35 different save available, it is obvious that MARVEL Field Engineers occupy a unique and exclusive position in the industry. They are eminently qualified to make expert and unbiased recommendations covering the type, size and model of metal sawing equipment best suited to individual requirements—the most efficient, most accurate, fastest, broadest in scope and the most economical.

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### **Personals**

D. F. Rundle . formerly with Campbell Wyant & Cannon Foundry Co., Muskegon, Mich., has taken a position as research metallurgist with Chrysler Corp.'s Central Engineering Division, Detroit.

L. F. Overhold has been appointed assistant manager of engineering for the International Harvester Co. of Australia Pty., Inc., Victoria.

W. J. Harris, Jr., (a), formerly with the Naval Research Laboratory, has accepted the post of executive secretary to the Minerals and Metals Advisory Board, National Research Council, Washington, D. C.

Lowell T. Smith (a) has been appointed as sist and metallurgical engineer in the metals department. Research and Development Division, Olin Industries. Inc., East Alton, Ill. He was formerly production supervisor in the tube mill, Lewin-Mathes Corp., Monsanto, Ill.

Alan R. Pels (2) has joined the staff of the research department of the Bridgeport Brass Co., Bridgeport, Conn. where he will be employed as a research metallurgist.

Walter Mathesius has retired from the presidency of Geneva Steel Co., Geneva, Ill., and is now consultant for the Koppers Co. Inc., Freyn Engineering Department, Chicago.

Mitchell H. Weisman (2) has been recalled to active duty as a lieutenant in the U. S. Air Forces and is now assigned to the Operations and Plans Office, Research Division, Wright Air Development Center at Wright-Patterson Air Force Base, Dayton, Ohio.

W. K. Culp (a) has been promoted to major in the U. S. Air Force and is now a radar instructor at Mather Air Force Base, Calif.

Franklin W. Daniels 🖨 and Michael J. Bolton 🖨 of General Electric Co.'s transformer and allied products division (Pittsfield, Mass.) were awarded the Mathewson Gold Medal recently by the American Institute of Mining and Metallurgical Engineers.

Willard N. Lynch, Jr., 
recently became president of the Keystone Drawn Steel Co., Spring City, Pa.

N. E. Philpot (a) is project manager, Industrial Branch, Productivity and Technical Assistance Division of the Mutual Security Agency, Washington, D. C.

Richard M. Treco (a), formerly with Sylvania Electric Products Inc., Bayside, N.Y., is research metallurgist at the Bridgeport Brass Co., Bridgeport, Conn.

George M. Staples III \( \extstyle \) has joined the staff of Columbia University as an assistant in the department of chemical engineering.

Edgar Landerman has recently accepted a position as manufacturing engineer with the metals joining laboratory, Westinghouse Corp., East Pittsburgh, Pa.

P. E. Holder (\$\,\text{th}\), formerly a sales representative in the American Cyanamid Co.'s Chicago district, has been appointed assistant district manager of the St. Louis district for the company's industrial chemicals division.



WHEN a large gear and forging plant wanted the fastest, most economical and efficient method of cleaning transmission housings and other metal parts, they decided upon Alvey-Ferguson job-engineered Washing Machines. Two machines in their

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METAL PROGRESS: PAGE 110





TRUE THE SURFACE. With this set-up true two diamond wheels at a time. Surfaces become uniform and perfectly flat. Usually takes about 15 to 30 minutes.



BRUSH THE MATRIX. Rotate the two wheels counter to rotation of Osborn wire wheel brush. This dressing removes some of the brass matrix. Leaves the diamonds exposed.

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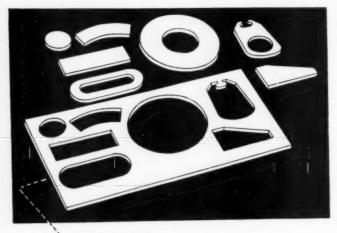
This is typical of many production aids available through your Osborn Brushing Analyst. Call him today or write The Osborn Manufacturing Company, Dept. 683, 5401 Hamilton Avenue, Cleveland 14, Ohio.



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SEE THE DIFFERENCE. Two wheels on left show grooves before truing. Surface is arched. Two wheels on right have been trued and dressed. Dressing increased cutting action 80%.



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### Personals

Guillian H. Clamer 3, president of the Ajax Group Co., Philadelphia, William A. Darrah . president of the Continental Industrial Engineers, Inc., Chicago, and Adolph W. Machlet &, chairman of the board, American Gas Furnace Co., Elizabeth, N. J., were awarded the Trinks Industrial Heating Award for outstanding contributions in the field of industrial heating. The award was established in honor of Wilabald Trinks, professor emeritus of mechanical engineering at Carnegie Institute of Technology, authority on the subject of industrial heating processes, industrial furnaces, and combustion problems.

Robert C. Kleindinst (4) of Buffalo has been appointed representative for New York State (excepting the metropolitan area) and Northern Pennsylvania by the Dollin Corp., Irvington, N. J., producers of zinc and aluminum die castings.

Nathaniel C. Fick , a member of the Department of Defense Research and Development Board, has been appointed director of the panel on metals and minerals of the newly established Committee on Materials.

William B. Klee, Jr., 🖨, formerly with Copperweld Steel Co., Glassport, Pa., now heads the Damascus Tube Co., Greenville, Pa.

Jerome W. Kaufman . formerly chief metallurgical engineer of the Naval Air Development Center at Johnsville, Pa., has been recalled to active duty as a captain, U. S. Army, and is now training at Aberdeen Proving Ground, Md., for subsequent procurement duties with the Ordnance Corps.

Albert J. Miller 3, who graduated from the University of Pittsburgh recently, has been employed as foreman of general services in the openhearth division of U. S. Steel's Duquesne District Works.

Robert E. Fisher . formerly associated with the General Motors Corp., is now with the atomic energy division of E. I. duPont de Nemours & Co., Wilmington, Del.

Charles B. Reymann 🖨 is now materials and process engineer for the Hayes Aircraft Corp., Birmingbam, Ala.

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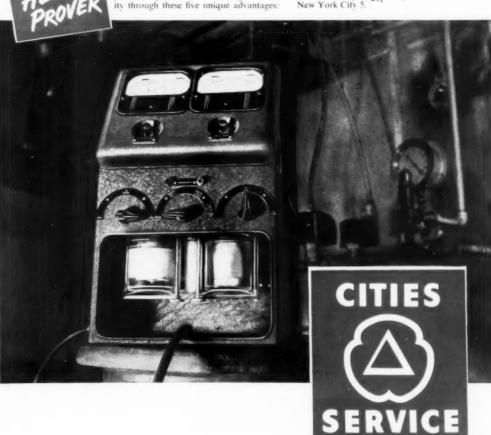
2. Simultaneous reading of oxygen and combustibles.

3. Direct measurement of oxygen and combustibles.

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These are real advantages in studying surface characteristics and examining parts.

- No. 26 is designed for examining small specimens.
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This is a precision instrument for determining the hardness of small areas, particles, and microscopic constituents in metals. A highly polished and lubricated specimen is moved by micrometer feed beneath an accurately ground diamond point. The pressure is precisely controlled so that hardness can be determined by the width of the resulting cut when measured under the microscope.

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INSTRUMENT DIVISION . BUFFALO IS, NEW YORK

### Friction and Wear at High Speeds and Pressures\*

THE FUNDAMENTAL investigations described in this report give some very interesting data which could be useful for research on such applications as retainers for high-speed bearings subject to "starvation lubrication" or dry friction. This work was initiated because of failure of materials now used for antifriction bearing retainers in applications subject to temperatures over 500° F., with periods of little or no lubrication and high sliding pressures.

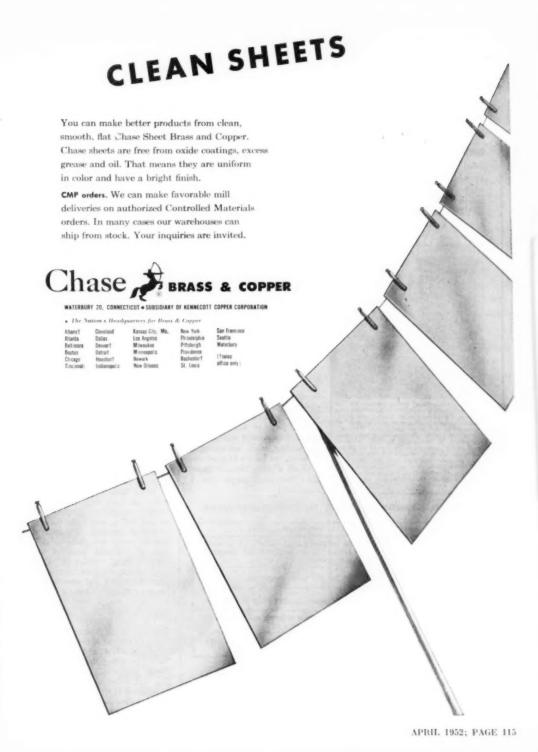
Jet engines and superchargers are applications in which bearing retainers have given considerable trouble. The critical phase of most high-speed bearing employment is at starting and for a short period thereafter. If little or no lubricant is present—as with rotor bearings of turbine-type aircraft engines after shutdown, which results from lubricants being vaporized from the bearing parts—dry metallic contact can occur between the retainers and the raceway or rolling elements.

At the high rotative speeds of these bearings (over 12,000 r.p.m.) and possible high pressures at points of local contact, it is not surprising that most materials fail due to excessive wear and galling. In addition to the normal pressures developed by the centrifugal force and driving load, stress concentrations result from roll skewing. Loads at the ends of separator pockets are sometimes formed; these produce plastic deformation of the material as distinct from abrasive wear. A successful separator material must have an adequate yield strength at operating temperature to inhibit plastic deformation.

The test apparatus consisted of a 13-in, diameter steel disk (S.A.E. 52100) hardened to Rockwell C-60 and circumferentially ground to a finish of 10 to 15 micro-in, (rms.) simulating the surface roughness of antifriction bearing cage locating members.

The %-in, diameter cylindrical specimens were of brass, Monel, 24S-T aluminum, Nichrome V, bronze, beryllium copper, nodular (Continued on p. 116)

\*Abstract of "Preliminary Investigation of Wear and Friction Properties Under Sliding Conditions of Materials Suitable for Cages of Rolling-Contact Bearings", by R. L. Johnson, M. A. Swikert and E. E. Bisson, Technical Note 2384, June 1951, National Advisory Committee for Aeronautics.



### AMERICAN CHEMICAL PAINT COMPANY AMBLER TO PENNA.

# Technical Service Data Sheet Subject: PROTECTING FRICTION SURFACES WITH GRANDDINE®

#### INTRODUCTION

Fabricators and product designers, particularly in the automotive field, are aware that even highly polished surfaces under friction weld, gall and score. One of the most inexpensive and practical methods of preventing this is to coat the metal to prevent metal-to-metal contact. With cast iron or steel, the "Thermoil-Granodine" manganese-iron phosphate coating provides a wear-resistant layer of unusual effectiveness.



Thermoil-Granodizing greatly prolongs the life of parts subject to friction. It protects the surface of products like the diese lengine lines shown above and the many moving parts of automobiles and other machines. 'Thermoil-Granodine' with its remarkable lubricating properties is particularly valuable in these and similar applications because of its ability to retain oil and maintain lubrication under high pressures and high velocities. This ACP wear-proofing chemical not only permits rapid break-in without scoring, sculfing and welding but also reduces subsequent wear on friction parts.

### "THERMOIL-GRANODINE" PROTECTS RUBBING PARTS

Thermoil-Granodizing temoves "fuzz" from ferrous metal friction surfaces and produces a coating of non-metallic, water-insoluble manganese-iron phosphate crystals which soak up and hold oil as bare untreated metal cannot do. The oiled crystalline "Thermoil-Granodine" coating on piston rings, pistons, cylinders, cylinder liners, cranks, cam-shafts, gears, tappets, valves, spiders and other rubbing parts, allows safe break-in operation, eliminates metal-to-metal contact, maintains lubrication and reduces the danger of scuffing, scoring, welding, galling and tearing of the metal. The work to be protectively treated is merely Thermoil-Granodized and oiled, usually with a soluble oil.

#### "THERMOIL-GRANODINE" MEETS THESE SPECIFICATIONS

SPECIFICATION NUMBER	SPECIFICATION TITLE				
MIL-C-162 <b>32</b> Type 1	Coatings — phosphate; oiled, slushed, or waxed (for ferrous metal surfaces) and phosphate treating compounds.				
AN-F-20 (See also U.S.A. 3-213)	Finishes, for electronic equipment.				
U.S.A. 57-0-2C Type II, Class A	Finishes, protective, for iron and steel parts.				
U.S.A. 51-70-1 Finish 22.02, Class A	Painting and finishing of fire control instruments; general specification for				
M-364	Navy aeronautical process specification for com- pound phosphate rust-proofing process.				



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PROTECTION PROBLEMS.



### Friction and Wear at High Speeds and Pressures

(Continued from p. 114) and gray east iron. One end was hemispherical and contacted the flat face of the steel disk which was rotated by a vertical shaft. After the specimens and disk were suitably cleaned before each test, the load was applied on the top of the specimens by a pneumatic diaphragm for friction tests and dead weights for wear tests.

Dry friction tests were made with a load of 100 g. and sliding speeds of 75 to 18,000 ft. per min. Frictional force was measured by a dynamometer ring equipped with strain gages, readings being obtained on a potentiometer converted to a friction-force indicator. The duration of load, speed and photographing of friction records were controlled by a synchronized timer which operated on a 3-sec, cycle, All dry friction tests were made on the same wear track with the friction readings being made at progressively higher speeds, approximately six readings being taken through the speed range.

Friction of boundary-lubricated surfaces was determined by rubbing a very thin film of a petroleum lubricant (Air Force 3519-2) on the disk using lens tissue. The speed in this test was maintained at 5000 ft. permin. with increasing loads in increments of 119 g. up to a maximum load of 1593 g. until either visible metallic transfer (galling) or friction increase denoted failure. It was believed that the initial lubricant films deposited on the disk were approaching monomolecular thickness at the point of contact.

Wear tests were conducted for 3 hr. on each material under dry surface conditions using two loads, 50 and 269 g., and a constant speed of 5000 ft. per min. The determination for wear was made by the volume of material removed at the hemispherical contact point. This was calculated from the observed area of contact and also by weighing the specimen. Weight loss could

be reproduced within ±10% for a given material.

The data obtained for dry friction shows that bronze had the lowest coefficient, approximately 0.20 for light load and low speeds; Nichrome V had the lowest for high speed, followed closely by Monel. The cast irons had a characteristic curve starting at approximately 0.40, rising to a maximum of 0.60 between (Continued on p. 118)

### **Customer Reports:**



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### Factors Affecting the Corrosion Resistance of Stainless Steels

Norman S. Mott Chief Chemist and Metallurgist The Cooper Alloy Foundry Co.

Much doubt exists today as to the influence on the corrosion resistance of stainless alloys of such factors as metal surface condition, grain size, cold working, chemical composition, magnetism and passivity. This discussion will attempt to explain these factors and their influence.

- 1. The smoother the surface of the metal, the better the corrosion resistance; thus ground or machined surfaces are better than those which are sand blasted, and a polished surface is the best.
- Small grain size in austenitic stainless steels decreases the tendency to intergranular attack, but the general over-all corrosion rate is not affected to any great extent by grain size.
- 3. Cold working austenitic stainless steels decreases the tendency to intergranular attack through the production of a small grain size and precipitation of carbides along strain lines rather than at the grain boundaries. Its effect on the overall corrosion rate, however, is to increase it.
- 4. Chemical elements such as chromium and aluminum are corrosion resistant in pxidizing acids, and others such as nickel, copper and tungsten are corrosion resistant in reducing baths. Some, such as molybdenum and silicon, are resistant to both. Alloyed, these properties may reverse to a certain extent, however, in general, their corrosion tendencies hold true for the more gross additions.

5. Magnetism in stainless steel is produced by the chemical comosition balance and or cold work. Its effect on the corrosion resistance is related only to that effect produced by these sources directly, and not to the magnetism as such. Chromium, silicon, molybdenum, columbium and titanium form a magnetic phase known as ferrite; and nickel, carbon and manganese form the non-magnetic phase austenite. The balance of these elements, considering their relative degrees of potency, determines whether or not the stainless steel is magnetic. The presence of ferrite in moderate amounts (5-10%) in the austenitic stainless alloys greatly decreases the tendency to intergranular corrosion but has little effect on the over-all corrosion rate. Ferritic-type alloys do not corrode intergranularly.

6. Passivity, a condition of nobility on low corrosion rate, is mainly a physicochemical surface characteristic of stainless steel, and is produced mainly by its chromium content. Passivity is first apparent around 12% and is not really effective until about 18% is reached. Additions of nickel increase the passive effect, and thus an 18 chrome 8 nickel alloy is more corrosion resistant than the 18% chrome type. Passivity is further promoted by additions of certain other elements. mainly molybdenum. The exact nature of passivity is still in dispute; however, it is known that while some media promote passivity, others break it down. Air, oxygen, adsorbed gases, nitric or chrome acids, and a high polish promote passivity, and chlorides. hydrochloric or sulfuric acids break it down. In dilute hydrochloric and sulfuric acids, 18-8S and 18-SMo remain passive until a critical percentage or temperature is reached, then passivity breaks down and active violent corrosion proceeds.

Copies of this article reprinted on heavy stock for concensent filing are available on request.



The COOPER ALLOY Foundry Co., Hillside, N.J.

### Friction and Wear at High Speeds and Pressures

(Continued from p. 116) 2000 and 6000 ft. per min. and returning to 0.40 at high speed.

Under boundary lubricated conditions at a constant speed (5000 ft, per min.) and variable load, the 24S-T aluminum had the lowest coefficient at low loads (400 g.), nodular iron and bronze at high loads, followed closely by Nichrome V. Monel had the most inconsistent friction curve of all, with a spread of more than 100%.

The results of wear tests show that brass, beryllium copper and aluminum are relatively poor, even at low loads. Monel at high loads behaves as badly as brass. The cast irons showed the lowest wear and greatest freedom from galling.

The prevention of galling is attributed to the formation of surface films. Whether a film can form depends on the characteristics of the material and its temperature; for Monel, beryllium copper and Nichrome V it may be due to an unstable oxide film that is formed, giving rise to variable friction and galling. Gray cast iron and nodular iron, on the other hand, would produce graphitic carbon as the deposited film, whereas bronze would produce a lead film.

Nodular cast iron, on the basis of its wear, would be indicated for bearing separator use, provided its strength is adequate for the purpose. Its self-contained graphite apparently provides a nonwelding interface, even at high temperatures. The oxide-forming films, particularly with the Nichrome V material, show interesting possibilities if they can be formed and renewed at all temperatures. Those of Monel apparently are very unstable throughout the temperature range.

#### COMMENTS BY REVIEWER

The results of this investigation confirm previous experience that the strength of the base material at operating temperatures and pressures is not the criterion for galling failure. Both nodular cast iron and Monel were tested at approximately the same Hertz stress level; yet nodular cast iron had minimum wear. Strength data for these are:

| TENSILE | YIELD | STRENGTH | STRENGTH | STRENGTH | Cast Iron | Monel | 110,000 | 100,000 |

The modulus of elasticity for the (Continued on p. 120)

It's con inside

these liquid gas

containers...

and polished copper

helps keep 'em that way

Spun Copper Inner Sphere Spun Brass Reinforcement High Vacuum (10-5mm of Hg Spun Copper and lower Outer Sphere Absorbing Soft Solder Chemical Bond Steel Casing Spun Brass Chemical Container

Cutaway section of a Hafman "Standard" Liquefied Gas Container, made in a range of sizes from 5 to 2000 liter capacity.

In the storage and transportation of liquefied gases such as air, oxygen, nitrogen, hydrogen and helium, evaporation losses are the big problem (containers can't be sealed because of explosion risks). If insulation is not adequate for the minus-452 F temperatures encountered, losses are costly.

Hofman Laboratories, Inc., of Newark, N. J. took a big forward step and made some radical changes in container design. Resembling a giant picnic vacuum bottle, the "Standard" Hofman Container is constructed of an inner and outer copper sphere separated by an extremely high vacuum. Bulky insulation is eliminated and, through the use of polished copper, surface radiation losses are greatly reduced.

Here, as in many other industrial applications, copper does a multi-purpose job better than any other metal by providing: (1) the ductility and malleability necessary for deep-spinning the hemispheres, (2) an unequalled metal for soldering, and (3) a smooth-surface, finegrain metal that will readily take a mirror-like finish.

Anaconda Metals are made by The American Brass Company, General Offices: Waterbury 20, Conn. 5285

This is Herb Basewit, design draftsman al Holman Laboratories, Inc., holding an urretouched polished capper lines shell lite a 25-liter container. A perferated spon-brais dish soldeted on one end holds a chemical which absorbs any leakage of gas ento the



ANACONDA
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There are two types of WILSON "ROCKWELL" Hardness Testers . . . Regular and Superficial. They come in many styles with accessories for testing flats, rods, rounds, and odd shapes. For micro-indentation hardness testing, there is the WILSON TUKON.

Write for information and let us make recommendations. \*Trade Mark Registered



WILSON
"ROCKWELL"
and TUKON
Hardness
Testers

### Friction and Wear at High Speeds and Pressures

(Continued from p. 118) iron is 23 million and for Monel it is 26 million psi.

The explanation as suggested in the paper would appear to be valid, that an active built-in material can produce a surface film having a shear plane of weakness less than the shear strength of either contacting bodies. It is known that effective "boundary lubrication" is due to films deposited on the surface, either from the fluid lubricant (extreme-pressure lubricants) or solid lubricants, such as graphite and molybdenum, or the less effective oxide films.

Because it is impossible to build up effective hydrodynamic lubrication between the sliding members at very high surface speeds due to narrow contacts and insufficient lubricant, it would appear that solid lubricants incorporated into the base material, such as graphite and molybdenum, are the most promising at present. In this respect graphitic steel might also have merit, Powdered metals incorporating low friction-active solids could be effective.

Although these films might be effective for the most severe applications of dry friction, an improvement that might be considered is that of the geometrical shape of separator load-carrying members to obtain the optimum hydrodynamic effect. Apparent contact area as such is not a parameter of effective galling prevention.

While the loads carried in friction tests with "boundary lubrication" show final Hertz pressures of only 640 psi, maximum after 48 sec., it would appear that the range of pressure for effective operation would be something less than the 55,000-psi, yield strength of cast iron to prevent local plastic deformation arising from stress concentrations caused by roller skewing.

E. G. Boden

### The Chromium Plating of Light-Metal Cylinders\*

A LUMINUM ALLOYS have long been realized to be very desirable for cylinders as well as pistons of internal combustion engines. This is because their thermal conductiv(Continued on p. 122)

\*Abstract of "Light Metal Chromed Cylinders", The Engineer, Vol. 192, July 27, 1951, p. 115.

# \* most any product in most any industry can be made better with

### DOWICIDE'A"



Dowicide® A is water soluble and is, therefore, easily added to water extended adhesive solutions giving them protection from decomposition caused by mold and bacterial attacks.



Dowicide A is used effectively to disinfect contaminated walls before the application of a mold resistant paint. Water extensible paints are preserved with Dowicide A.



Dowicide A is used to disinfect buildings, egg storage rooms, and poultry feeding stations. When used in the wax emulsion coating, it protects citrus fruits from blue mold and stem-end rot.



In the paper industry, Dowicide A is used to protect paper sizing and coating solutions from mold and bacterial attack, both during use and storage.



Dowicide A protects soluble oil emulsions from bacterial decomposition and the accompanying unpleasant odors, emulsion breakdown, and the clogging of screens.



Rayon or silk thread in storage is protected against mildew by the addition of Dowicide A. It is also used to preserve protein, animal glue, casein and starch sizing solutions.



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Dowicide Department DC-114, Midland, Michigan
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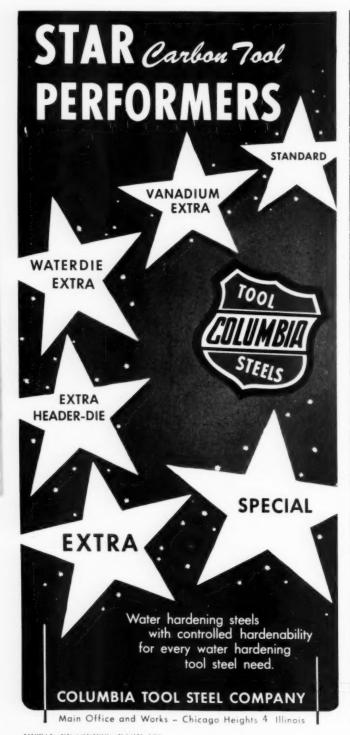
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I am interested in using Dowicide Products for





### The Chromium Plating of Light-Metal Cylinders

(Continued from p. 120) ity is considerably greater than that of cast iron, especially in air-cooled engines (particularly of the two-stroke type). Also, use of these alloys permits matching the thermal expansion of the aluminum pistons so commonly used now-adays so that excessive clearance over the whole temperature range of operation is avoided. On the other hand, its poor abrasion re-

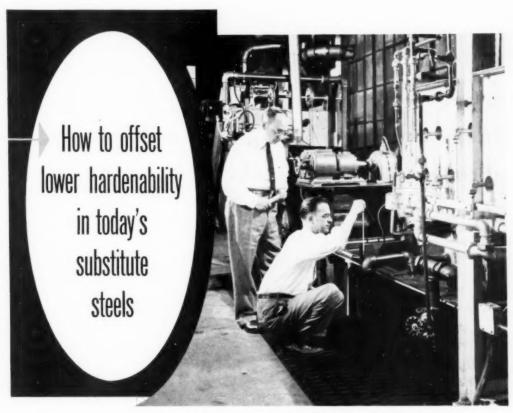
of operation is avoided. On the other hand, its poor abrasion resistance and tendency to gall were long considered to make use of aluminum alloys impracticable.

The earliest successful solution of this problem was to use east iron cylinder liners in aluminum blocks. thus combining the good friction characteristics of the cast iron liner with the high thermal conductivity of the aluminum block. The liners were either pressed-in or cast-in by a rather ingenious but complicated process. However, neither method was entirely satisfactory. In the first method the heat flow is considerably obstructed by the interface, and the differential thermal expansion of the two materials causes distortion of the cylinder contour as well as causing separation at the interface. The cast-in method is expensive and the thermal barrier provided by the cast iron is still present to some extent.

Independently of these advances a special chromium plating of cast iron cylinder barrels began to make its appearance. Chromium plating has a two-fold advantage: it not only has high abrasion resistance which considerably reduces the wear of cylinder bores in dusty or sandy environment, but it also permits a simple salvage by rebuilding the cylinder wall back to its original diameter. Its value was particularly evident in the engines of planes used in the North African campaign during the recent war, where both the sand abrasion and the engine salvage problems presented a serious problem.

This plating was initially applied to cast iron cylinders but more recently to aluminum alloy cylinders as well; it seems to solve the wear resistance problem of the latter. (It is not, however, the usual "bright chromium" surface used for decorative purposes.) Oil seems to spread with difficulty on this plated surface, and an abrasive particle, because it cannot be imbedded, has no place to go to get

(Continued on p. 125)



### Switch to GULF SUPER-QUENCH, the oil with greater quenching power

Is the current alloy shortage creating a heattreating problem for you? Must you accept alloy steels with less nickel, molybdenum, and chromium than you originally specified? Then you'll be interested in the performance of Gulf Super-Quench. Because of its greater quenching power, this outstanding quenching oil helps offset the lower hardenability of today's substitute steels.

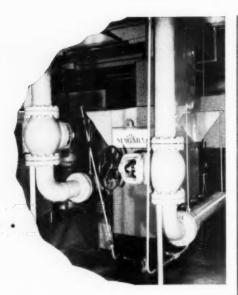
Gulf Super-Quench passes through the vapor stage far more quickly than conventional quenching oils. This means that the cooling rate is extremely fast at the outset, an important factor in the depth and uniformity of hardening. In the succeeding stages Gulf Super-Quench has a slow cooling rate, like that of conventional quenching oils, and therefore has the same minimum tendency toward distortion and cracking.

Greater quenching power of Gulf Super-Quench adds up to greater depth of hardening and more uniform hardness! One of the most practical advantages of Gulf Super-Quench is greater uniformity of results on steels of variable hardenability.

For further information on Gulf Super-Quench, call in a Gulf Sales Engineer today. Write, wire, or phone your nearest Gulf office.



How to get drier or cooler gases . .



NIAGARA AERO AFTER COOLER cools a compressed gas, or air, below the temperature of the surrounding atmosphere, thus preventing the condensation of moisture in your lines. The gas will contain only half of the moisture left in it by conventional methods. Even drier gas can be produced if you require it.

In working with controlled atmospheres of inert gases to prevent undesired reactions, this dryness of the gas at low cost is a great advantage. The cost of the Niagara method is low because it uses evaporative cooling, saving 95% of the cost of cooling water (and its piping and pumping). This direct saving of cost pays for the Niagara cooler in less than two years.

If you use compressed air to operate tools or pneumatic equipment you save much in water and oil damage to tools and equipment, and in water damage to materials by using the Niagara Aero After Cooler.

Write for a bulletin, or ask nearest Niagara Field Engineer if you have a problem involving the industrial use of air.

### NIAGARA BLOWER COMPANY

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Experienced Field Engineers in Principal Cities of U.S. and Canada

METAL PROGRESS; PAGE 124

### The Chromium Plating of Light-Metal Cylinders

(Continued from p. 122) out of the way. A number of special platings have been developed which eliminate these difficulties and provide an excellent cylinder barrel surface in many respects. All of these have this characteristic in common, that the familiar smooth chromium surface is replaced with one in which there are frequent minute indentations. These indentations have the property of (a) holding oil, (b) interrupting any galling that might start, and (c) providing a place for an abrasive or wear particle to escape from between the rubbing surfaces without scoring them.

Such indented or interrupted surfaces have been produced in a number of ways. Possibly the best known is that developed and patented by the H. van der Horst Corp. By this process the chromium is plated on a smooth surface to a depth of 0.002 to 0.003 in, and more than necessary for the final bore size. The cylinder is then removed from the plating tank and put into another tank, containing another solution with the same anodes and the same setup, but in which the current is reversed for a few minutes. As a result, some of the plated chromium is removed, not in a uniform layer but in localized regions, thus producing what is often called a porous chromium surface containing a multitude of pits and depressions evenly dispersed over the whole cylinder wall.

The porous chromium plating of aluminum cylinders, also developed by the van der Horst Corp. during the last war, is not basically different from that for the steel or cast iron cylinder described above, except for the tendency of aluminum to form an oxide layer which prevents its bonding with electrolytic deposits of other metals. To overcome this difficulty the cylinder to be plated is first dipped in a strong solution of caustic and sodium zincate. The caustic dissolves the oxide film to reveal the bare metal and also roughens it slightly which contributes to the indented character of the final surface. The sodium zincate forms a protective film, which is exceedingly thin and even, over the plating surface as the oxide is dissolved but which is readily dissolved in the chromic acid of the subsequent plating bath. After

(Continued on p. 126)



Jet exhaust gases that reach temperatures of more than 2,000 deg. F. and speeds as high as 1,800 m.p.h. are easily handled by the new HAYNES cobalt-base alloy No. 25. In fact, this alloy was one of the few commercially available materials that could even be considered for the hottest parts of the afterburner pictured here.

The afterburner is installed behind the jet engine and increases the thrust of the plane by burning fuel with the unused oxygen in the turbine exhaust. Finding an alloy that would stand up under the heat and stress of this operation was really a tough problem. The material had to be strong at high temperatures and resistant to the oxidizing action of the corrosive exhaust gases. In addition, it had to be capable of fabrication by drawing, forming, and welding.

HAYNES alloy No. 25 has a unique combination of all these properties. For complete information on this alloy, write for the 12-page booklet, "HAYNES Alloy No. 25."

### HAYNES

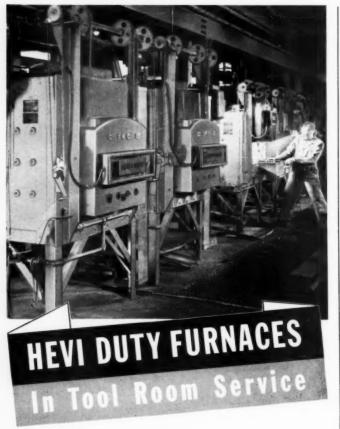
alloys

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A Division of Union Carbide and Carbon Corporation

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"Haynes" is a trade-mark of Union Carlode and Carlon Corporation.



### Are Versatile .... and Dependable

These Hevi Duty Box Furnaces at the A. O. Smith Corp. of Milwaukee, Wisconsin are used for hardening production tools that vary in weight from a few ounces to several hundred pounds. Hevi Duty Furnaces provide the uniform temperatures needed for precision heat treating.

Send for bulletins HD-341 and HD-441

DRY TYPE TRANSFORMERS - CONSTANT CURRENT REGULATORS

MILWAUKEE 1, WISCONSIN

### The Chromium Plating of Light-Metal Cylinders

(Continued from p. 124)

plating, the cylinder is honed to its accurate diameter; this removes the surface irregularities down to about mid-depth and provides a smooth plateau over which the rubbing load is distributed.

Results obtained by the Mall Tool Co. of Chicago using this method on small portable aircooled two-stroke engines have been very encouraging. Compared to an engine having a pressed-in steel liner, the plated aluminum cylinder makes possible an engine which is smaller and lighter and yet de-

velops 32% more power.

In Europe the Mahle concern. Stuttgart, have obtained equally encouraging results with aluminum cylinder bores that have indentations in the chromium plating which are made in a somewhat different manner. The cylinder. after the final fine-boring operation, is machined with a knurling tool which leaves a regular pattern of indentations on the surface. Inasmuch as the deposit follows the contour of the base metal, the plated surface has all the characteristics of the latter. That is, evenly dispersed recesses for the retention of Inbricant and reception of foreign particles. The useful life of the engine was found to be increased sufficiently to offset the increased cost of the plating step.

Another possibility is to chromium plate only the piston and rings and this is being tested at present by the Mahle concern. If successful, it should be considerably cheaper than plating the cylinders and might easily give a great impetus to a more general adoption of light-metal cylinders, particularly in air-cooled engines for road vehicles.

J. T. BURWELL, JR.

### Spheroidal-Graphite Cast Iron for Crankshafts\*

 ${f A}^{ ext{CICULAR}}$  and spheroidal-graphite types of east iron have found extensive use in Great Britain in internal combustion engine and stationary diesel engine crankshaft castings. From an engineering

\*Abstract of "Cast Iron Crankshafts, With Special Reference to Acicular and Spheroidal-Graphite Cast Irons", by A. B. Everest, Foundry Trade Journal, Vol. 91, Dec. 6, 1951, p. 643-650,

viewpoint, east iron crankshafts offer a number of important advantages: reduced weight, reduced machining time, and elimination of heat treating operations—properties which favor their use even when steel is available. Production economy is another benefit.

#### ACICULAR CAST IRON

Early in the development of cast iron for crankshafts in the U.S.A., alloy composition containing nickel and molybdenum was adopted, as it was found that this alloy combination gave exceptionally high strength. Further study established that these high mechanical properties could be obtained at will by using molybdenum in conjunction with nickel, the latter being varied in relation to the cooling rate or section thickness of the casting. The characteristic structure developed in these nickel-molybdenum east irons is closely related to "bainite", and this type of cast iron is now known as acicular cast iron.

The tensile strength of acicular cast iron can vary from 55,000 to 77,000 psi, and can be further improved by heat treatment. Its other mechanical properties are correspondingly high—its impact or shock resistance is at least twice that of the best pearlitic cast iron.

The graphite in the normal acicular iron is in the flake form; consequently this iron shares the good damping properties associated with flake-graphite irons and, in common with all the other cast irons, it shows a low notch sensitivity in fatigue tests. Wear resistance of acicular cast iron is excellent. Although its hardness is relatively high, it can be readily machined.

Considerable experience is now available on the use of the nickel-molybdenum acicular cast iron crankshafts in internal combustion engines. The economy in using acicular cast iron crankshafts as compared with the conventional type of steel forging or stamping is substantial.

On engine test, torsional vibration diagrams on a shaft for 6-cylinder diesel engine, developing 240 h.p. at 1500 r.p.m., have shown that the steel crankshaft developed a torsional shear stress of 9100 psi., due to the sixth-order critical speed, and this was reduced to 4250 psi. in the cast iron crankshaft.

Satisfactory fatigue strength is demonstrated by acicular east iron crankshafts. For example, one maker, who has recently been studying this material for a six-(Continued on p. 128)





Typical parts heat treated in Hevi Duty furnaces at the Union Special Machine Co.

# union SPECIAL heat treats precision parts in HEVI DUTY FURNACES

Over 100 different heat treating operations are represented in one Union Special industrial sewing machine. All the carburizing, dry cyaniding and bright annealing of precision ground shafts, bearings, journals, castings and eccentrics is done in versatile Hevi Duty Vertical Retort Furnaces.

Walter Weinwurm, chief metallurgist at Union Special, says "Our Hevi Duty furnaces do an exceptionally good job of heat treating precision parts. The work comes out of the furnaces clean with no scale or oxidation."

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Heat Treating Furnaces... Electric Exclusively
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Check the job to be done and you will find a Firecrete\* product that will do it well. For special refractory shapes or linings it's simply mix and cast. The new shape or lining air-hardens and is ready for service within 24 hours. Other advantages include—no drying shrinkage, negligible firing shrinkage, high resistance to spalling.

### For USE 3000F — 3X FIRECRETE

This new member of the Firecrete family effectively withstands soaking temperatures up to a full 3000F. Provides savings through longer life and reduced shutdowns.

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A high heat-duty refractory composed of an exceptionally heat-resistant base. Specially developed for service between 2400F and 2800F.

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The most generally applicable type of Firecrete. Finely ground, permitting casting of shapes or linings as thin as  $11_2^n$ .

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A lightweight insulating refractory concrete with unusually low thermal conductivity, low heat storage capacity and high resistance to spalling.

The above Firecrete materials can be used in combination where varying temperature and service conditions are encountered.

For patching and gunning, use 3X BLAZECRETE. For temperatures to 3000F. It has exceptional adherence qualities, can be flipped into place with a trowel without ramming or tamping.

For further information, write to Johns-Manville, Box 290, New York 16, N. Y.



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### Johns-Manville FIRECRETE

"The Standard in Castables"

### Spheroidal-Graphite Cast Iron for Crankshafts

(Continued from p. 127)

throw marine diesel crankshaft. states that test-bars cut from an extension of the crankshaft casting give a fatigue strength on the plain bar of 21,300 psi. The use of a notch in the test-bar only slightly reduces this figure, and a strength of 20,600 psi, is reported. Under similar conditions of test, the values for steel are normally of the order of 17,000 psi. Torsion fatigue tests on unnotched bars gave 12,000 psi., and similar tests conducted on bars containing a drilled hole, so positioned as to give maximum concentration of stress, gave 8500 psi. Notch sensitivity of cast iron is much less than for steel, with the result that in practice there is appreciably less danger of fatigue failure due to stress concentration by such discontinuities as oil holes.

#### SPHEROIDAL CAST IRON

Lately, attention has been drawn to a product known variously as spheroidal-graphite cast iron, nodular cast iron or ductile cast iron. The essential characteristic of these irons is that the graphite has assumed the form of compact spherical particles. These have a very much smaller deleterious effect in breaking up the metallic matrix of the metal, allow the properties of the metallic matrix to be more fully realized, and eliminate the innumerable notches which act as stress raisers within the body of normal cast iron.

The mechanical properties of these new cast irons are of a high order, and approach very much more nearly those common to the steel-like matrix of the metal. Their strength under various forms of test is about double that of conventional cast iron. The elastic modulus is high, but of particular interest is the fact that, like other cast irons, the notch sensitivity of the material is low compared to steel, as shown by the relatively low reduction in the endurancelimit figure, which included a notch in the test-piece. The net result of this is that the endurance limit under notched conditions is. for the new material, frequently as high or even greater than that of steel as used for crankshafts.

As would be expected from the form of graphite, the vibrationdamping capacity of the new cast irons lies midway between that of

(Continued on p. 146)

# Facts you should know about U.S.S GARILLOY STEELS

# Free-cutting CARILLOY FC minimizes shaft breakage on Clearfield Maximullers

 If you work in a clay products plant, you know all about the Clearfield Maximuller made by the Clearfield Machine Company, Clearfield, Pa.

The Maximuller shown here is used to grind all kinds of clays for ceramics, refractories, etc. The huge 7½ ton mullers, each supported by its own shaft, are the grinding members. As the raw clay passes under the mullers and is crushed, the muller supporting shafts are subjected to bending and reversing loads that ordinary steel cannot endure. That's why these shafts are now made from U.S.S. Carillov FC steel—a free-cutting alloy steel that is furnished already quenched and tempered to the hardness required.

By using Carillov FC Steel, the Clearfield engineers have accomplished three things. They obtain a tensile strength in the shaft of 140,000 to 165,000 psi—which gives them a highly desirable factor of safety.

One of the two 7-inch diameter Carilloy FC shafts being installed on a Clearfield 82 Maximuller. Each shaft must support and guide a 7½ ton muller, withstanding tremendous jarring as well as bending and twisting loads.

Clearfield uses Carillov FC for highly stressed shafts in practically all models in their wide line of mixing equipment.

Because quenched and tempered Carilloy FC is free cutting, these shalts are machined faster with excellent surface finish.

And, because the bars arrive from the mill already quenched and tempered to 258-331 Brinell, they obtain the exact hardness desired without any need for subsequent heat treating with its attendant hazards of warpage and scaling. What's more, because the steel has better machinability than other steels of comparable strength and hardness, they are now machining shafts faster than before and with better surface finish.

U-S-S Free-Cutting Carillory steel is available in bar form, quenched and tempered from 255 to 375 Brinell or annealed, in all sizes of rounds from 5% to 8% diameter. If your job requires forging, we can also furnish a complete range of hot rolled bar and semi-finished sizes.

Cost: Carilloy FC costs only a fraction of a cent more than ordinary, thorough-hard-ening alloy steels.



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Division of United STATES STEEL COMPANY, PYTTSBURGE

UNITED STREET STEEL SUPPLIES COMPANY, NEW YORK



# "Every man in our shop is an expert"



# says James Henderson

• The machine shops are vitally important at the Homestead District Works Forge Division. If you could visit them, you'd see machines that are really whoppers—like the 96-inch lathe that can turn and bore a 110-ton piece that's 8 feet in diameter, and 66 feet long. If you talked to Machinist James Henderson, who operates the lathe, the conversation might go like this:

YOU: "How old were you when you started in the mill?"

HENDERSON: "Fourteen. I started in the Homestead Works as a messenger in 1918."

YOU: "How long were you a messenger?"

**HENDERSON:** "Four years. Then when I was 18, I started as an apprentice machinist in the maintenance shop."

YOU: "What kind of work did you do!"

HENDERSON: "Practically everything. First, of course, I had to operate all the machines, It was good training, because in a big mill like this, if something broke down—a big cylinder bushing or a special bolt—we couldn't wait for outside replacements so we'd make new parts for the job. We had to work fast, too, because sometimes a whole production line would be shut down."

YOU: "What did you do next?"

HENDERSON: "After almost 20 years in the maintenance shop, I came here. I've been on the 96-inch lathe ever since."

YOU: "That means you've been a machinist now for 30 years. Did you like coming to the forge department?"

HENDERSON: "It was the greatest experience I ever had in this mill. In a way, I had to learn all over again. I remember how scared I was the first time I had to bore and ream a long hole through one of these big forgings. It was just like this job—we're boring a hole 25 feet long, to a .001" diameter tolerance."

YOU: "Do you ever run into any trouble?"

HINDERSON: "We sure do. Like when we're drilling a hole. You get an awful sinking feeling when the rod comes out without the drill on the end. It's a break-off. The drill breaks off and stays galled in the hole. Sometimes we spend as much as 8 hours trying to pull that drill out with special tongs."

YOU: "I guess a mistake would be mighty extensive."

MENDERSON: "Yes. Here, a mistake could cost thousands of dollars. But we don't make many mistakes."

YOU: "What would you say is the most important thing about making quality forgings?"

HENDERSON: "Well, you've got to have the steel and the machines. But I think the men are most important. Like here, the furnace man, pressman, machinist, and heat treater all have to work together. Any one man can foul up a job. We almost never have trouble, so I figure almost every man in the shop is an expert."

When you buy forgings from United States Steel Company, men like James Henderson work on them. We'll match their work against the finest in the land. For more information on U.S.S Quality Forgings, write to United States Steel Company, 525 William Penn Place, Pittsburgh 30, Pa.



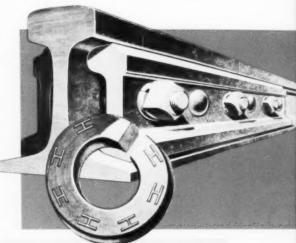
# Facts you should know about U.S.S GARILLOY STEELS

# 18,000,000 Carilloy spring washers used without one reported failure!

### thanks to U·S·S metallurgical assistance

HUBBARD & COMPANY, Tool Division, Pittsburgh, Pa., is a major producer of rail joint spring washers. These vital washers are used on the bolts of the joint bars that connect sections of railroad rails. Battering and wear at the rail ends is reduced due to the high bolt tension caused by the reactive pressure of these CARILLOY steel washers.

Some time ago, our metallurgists got together with Hubbard engineers and came up with a vastly improved method of heat treating these alloy steel washers. This heat treating system has achieved uniform heating, precisely timed quenching and fool-proof tempering. Result: a higher quality product, more uniform than ever before.



Here are the actual test results on a typical production run at Hubbard & Company. At left is the finished washer ready for delivery. Middle picture shows the washer after the 90° twist test required by specifications. As shown at the right, Hubbard spring washers will consistently withstand a twist test far greater than required.



At Hubbard, this variable speed conveyor removes spring washers from the quench tank on a precise time cycle.

Here's what B. J. McTighe, Superintendent of Hubbard's Tool Division says:

"Since installing our new heat treating system, we've sold about 18,000,000 spring washers without one reported failure. The improved heat treatment, suggested by United States Steel, has resulted in more uniform structure, better mechanical properties and a retention of spring properties under all conditions.

"These spiral spring washers, made from Carilloy 9260 steel, are hardened to an average of 49/52 Rockwell C. Despite this high hardness, the washers easily meet the specification requiring a 90° cold twist in the fully heat treated condition. Our own shop control limits are even more severe than this to make sure that we meet and exceed railroad standards. We think the superior performance is due to our improved heat treating system."

If you're having trouble handling lean alloys, we may be able to suggest heat treatment methods that will give you more uniform hardness, less rejects and less retreatments. Simply call or write our nearest district sales office.

COLUMBIA-GENEVA STEEL .... TENNESSEE COAL & IRON .... UNITED STATES STEEL SUPPLY, WAREHOUSE DISTRIBUTORS

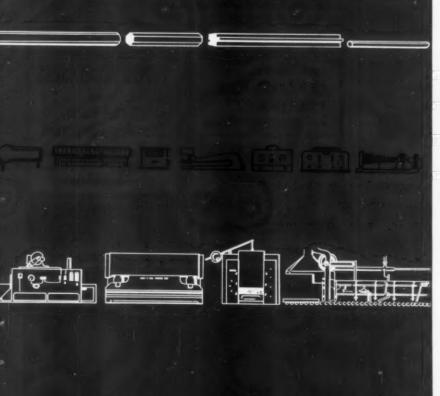
Division of UNITED STATES STEEL COMPANY, PITTSDURGH

SHITES STATES STEEL EXPOST COMPANY, NEW YORK

METAL PROGRESS

### **BULLETIN BOARD**

THE BUYERS' GUIDE FOR METALS ENGINEERS



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- 139 BRAZING
- 130 CASTINGS
- 130 CLEANING &
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- 136 137 TOOL STEEL
- 139 WELDING

.





LIST NO. 17 ON INFO COUPON PAGE 139

#### Time available CENTRIFUGAL CASTING

Non-Gran supplies both aluminum and tin bronze centrifugal castings, as well as bronze sand castings. Send prints. American Non-Gran Bronze Co., Berwyn, Pa.



LIST NO. 3 ON INFO-COUPON PAGE 139

#### CiRCO VAPOR DEGREASERS and **Metal Parts Cleaning Equipment** PER-SOLV (Perchlorethylene) CIRCO-SOLV (Trichlorethylene)

Write for Bulletin

#### TOPPER EQUIPMENT COMPANY MATAWAN, NEW JERSEY

DIFFICES IN PRINCIPAL CITIES
MANUFACTURERS OF VAPOR DEGREEASES
AND METAL PARTS CLEANING EQUIPMENT

10 ON INFO-COUPON PAGE



METAL PROGRESS; PAGE 130



reference to 20th Century Drawn Steel Shot will emphasize its highest quality, economy and ability to stand hard use

THE CLEVELAND



One Of The World's Largest Products Of Quart, Abrasian statement Copyrighted Trade Name: Hard Line Cut Wiss Practice

LIST NO. 13 ON INFO COUPON PAGE 139



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Foundry Snagging—Billet Surfacing—Centerless Grinding Cutting and Surfacing concrete,

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Raybestos-Manhattan, Inc. MANHATTAN RUBBER DIVISION 92 TOWNSEND ST. - PASSAIC, N. J.





strictions on the metals, the precious metal, rhodium, becomes impor-tant as a replacement for them, especially for small articles and parts.

Rhodium is hard and brilliantly white and it cannot tarnish. No acid nor mix-ture of acids attack it. Our solution has excellent throwing power.

Suggested objects for plating with rhodium are optical mounts, contacts for communication equipment, radar components, surgical instruments and pen and pencil sets. The practical plater's own experience will suggest many others to him.

Commercial rhodium plating was developed in our laboratories. Baker Rho-dium Plating Solution is the original and is made under the direction of the men who developed the process.

Let us send you Directions for Rhodium Plating.



LIST NO. 7 ON INFO COUPON PAGE 139 METAL PROGRESS; PAGE 131



#### HEAT TREATING FURNACES

for Every Heat Treating Process

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DIRECT FIRED

CIRC-AIR DRAW
FURNACES

CIRC-AIR NICARB

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Specially Engineered for Your Particular Needs

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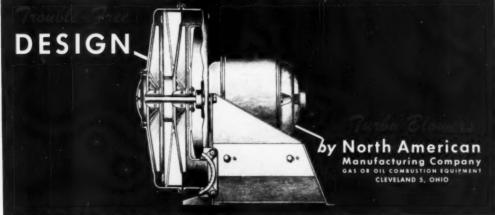
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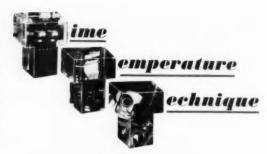
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METAL PROGRESS; PAGE 136

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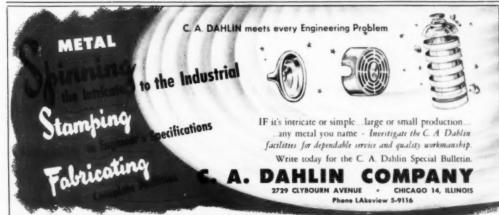
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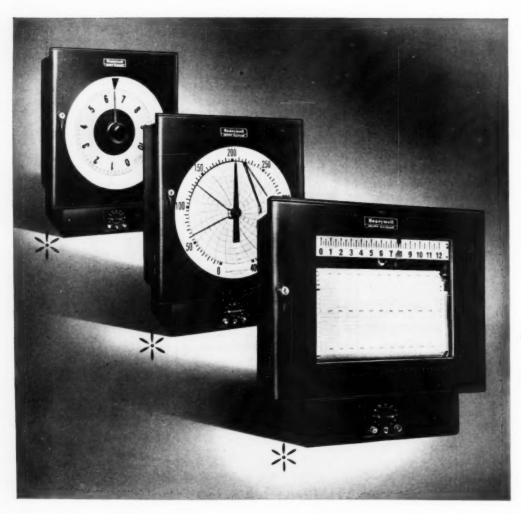
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METAL PROGRESS; PAGE 139

# For peak performance...





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FOR STRAIGHT LINE TEMPERATURE RECORDS When heat input should vary like this . . .

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the same position-proportioning action as Electr-O-Line Control, but reset must be manually operated. load, fuel supply pressure and heat content of fuel.

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The control instrument can be an ElectroniK strip chart or circular chart recorder, or circular scale indicator. Any of these instrument models can be supplied complete with Electr-O-Line, Electr-O-Pulse or Manual Reset Control. For modernizing existing installations, the control relays are available separately.

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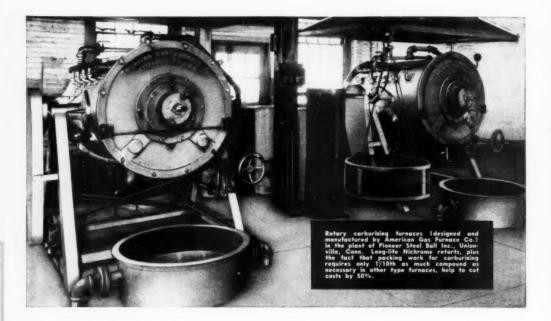
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under just such conditions that furnace components made with Driver-Harris alloys show to best advantage—prove the most dependable and economical.

Here's a case in point: The batch-type rotary carburizing furnaces shown here are two of a battery equipped with Nichrome- retorts. Operation consists in charging each furnace with 450 lbs. of steel balls, together with carburizing compound, and bringing to a temperature of 1650-E within 1½ hours. Individual furnaces are then held at temperature from one to several hours—depending upon the case depth required. When carburizing is completed, they are tilted to permit the work to spill out. Immediately after being emptied, they are re-charged.

On the average, each hot Nichrome retort is quenched, by having 450 lbs. of cold work dumped into it, every

3 hours-and is then brought rapidly up to 1650° again.

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In selecting your heat-treating equipment, it will profit you to remember the important economies afforded by Nichrome and Chromax. These alloys are at present on allocation, but we shall be glad to make recommendations based on your particular needs and serve you to the best of our ability.



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METAL PROGRESS: PAGE 142

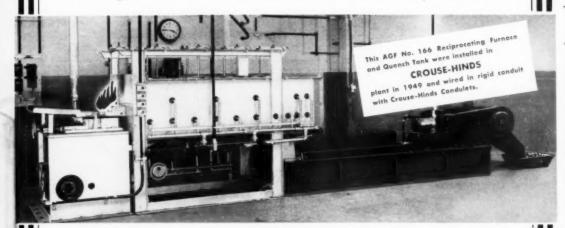


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"They call this a reciprocating controlled atmosphere furnace with quench tank and conveyor, used for carburizing and quenching clips and various other perts requiring certain hardness characteristics with high yield point, without embritlement. The furnace is controlled within plus or minus 2½ and has been in steady use since November 1949.

"As a comparison, the operation was formerly done by heating in a salt both in which both quantity and quality were unsatisfactory, requiring the services of an operator working under hard and undesirable conditions.

"The present operation, being fully automatic except for eccasionally dumping fresh parts into the feed chute and removing a full box from the quench conveyor, gives us a product of the desired quality and quantity."

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- · Nothing to do but charge
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- Hardening and quenching one
- continuous automatic operation

  Dependably uniform hardening
- No messy sait to clean
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- Clean hardening results
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- Low cost of operation
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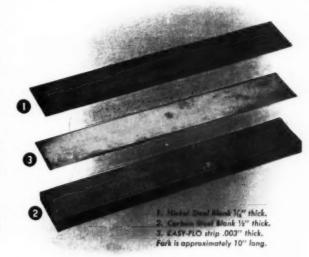


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THE FORK PROPER is made by joining the Nickel Steel blank (1) to the Carbon Steel blank (2) with EASY-FLO (3). The two metals have opposite thermoelastic characteristics, and, by proportioning them properly, a fork is produced that is extremely accurate and insensitive to variations in temperature.

● And now we quote in part from Riverbank's description — which says, EASY-FLO "is preferred for this application since it is imperative that a clean, strong and uniform junction be obtained. Furthermore, the alloy must not be affected by continuous displacement since a 1,000 cycle fork, for example, will vibrate 86,400,000 times in one day."

And again, the required extreme accuracy "cannot be obtained unless a perfect silver alloy joint is accomplished." Well, EASY-FLO accomplished it... and proves once again that it is a top performer where quality results count.



#### BULLETIN 20 TELLS ALL ABOUT EASY-FLO BRAZING

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SSRAR Bulletin N.I.

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#### Spheroidal-Graphite Cast Iron for Crankshafts

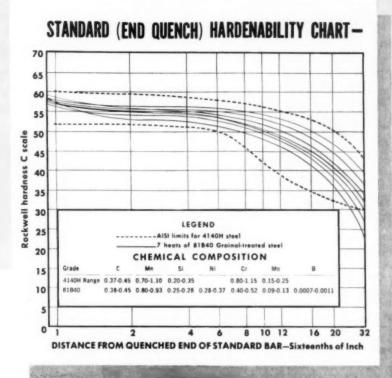
(Continued from p. 128)

steel and the normal flake-graphite types; consequently, from this point of view the new iron is perhaps not so favorable for crankshafts. On the other hand, the tests which have been carried out to date show that the wear resistance of the new iron is very good and compares favorably with the best of other types of high-duty cast iron.

Spheroidal-graphite cast iron is made by the addition of small amounts of cerium, magnesium or other metals to the iron. The magnesium process has proved the most successful and economic. This new iron has been considered of interest for east crankshafts, and a considerable amount of experimental work attests its suitability for this application; however, it must be emphasized that much of the work on spheroidal-graphite cast iron has been carried out on the material in the annealed condition, in which a short high-temperature anneal is given to break down the pearlitic matrix to the ferritic state and to develop high ductility. The elongation of the annealed material is of the order of 10 to 25%, whereas the elongation of the material as-cast is generally not in excess of 3% unless special compositions are selected. It is anticipated that for applications such as cast crankshafts, where wear resistance is vital, attention will be focused on the pearlitic low-ductility type, as the general experience is that cast irons with microstructures including ferrite are inferior in their wear resistance.

No figures are available for the endurance limit of this grade, but some figures have been published for the annealed ferritic grade and they emphasize that, as for other cast irons, the new type has a low notch sensitivity. The actual enourance limits of the pearlitic grade would be expected to be, if anything, rather higher. In the meantime, preliminary reports on tests carried out on crankshafts are distinctly encouraging. It is true that the new iron has not the high degree of damping capacity shown by the flake graphite types in fact, the damping capacity is nearer that of steel than of cast iron. The higher mechanical properties of the new iron offer the possibility of producing crankshafts with properties much nearer to those of steel.

(Continued on p. 148)



Consistent
Hardenability obtained
in Boron Steels
made with
GRAINAL ALLOYS

The most common test for boron steels is measurement of hardenability by the end quench or Jominy hardenability test. Today's steel substitutions are made on the basis of similar hardenability since a reasonable prediction can thus be made of the hardness and strength of a given part.

The curves above show the relationship between the hardenability of a series of seven heats of 81B40 steel and the hardenability band for 4140H steel, which it often replaces. The 81B40 heats were made in one electric furnace shop, and the remarkably consistent hardenability shown by the curves was obtained by the use of Grainal alloy as the means of adding the boron.

Grainal alloy as the means of adding the boron.

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#### Spheroidal-Graphite Cast Iron for Crankshafts

(Continued from p. 146)
while having the full production
economies possible with a readily

cast metal.

Preliminary wear tests have been reported, and show that the resistance to wear of the spheroidalgraphite iron under laboratory conditions is good. It is reported that the wear resistance of such cast iron under lubricated conditions is excellent, in particular when free ferrite is absent. There seems no doubt that the spheroidal-graphite iron will be of great interest to engine designers, not only for crankshafts, but for other items, including rocker arms, pistons, cylinder heads, liners, and timing gears. Tests have been carried out on spheroidal-graphite cast iron with an acicular matrix, developed by suitable additions of nickel and molybdenum. There are indications that tensile strength in this type of material can easily reach 50 to 60 tons per sq.in., with the other mechanical properties proportionately increased.

D. C. WILLIAMS

#### High-Temperature Alloy for Rotor Blades\*

A STUDY of the influence of systematic variations in composition and heat treatment on creep and rupture properties led to a wrought austenitic alloy having a composition of 0.3 C, 0.8 Mn, 0.3 Si, 19 Cr, 12 Ni, 45 Co, 2.8 V, 2.0 Mo, 1.2 Cb and 16 Fe.

The heat treatment of this alloy, known as G32, is to oil quench from 2335° F. after a 10-min, soak and then age for 46 hr. at 1380° F.

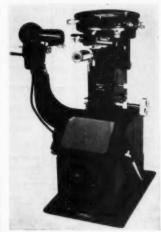
Starting with a base composition of 20 Cr - 20 Ni - 20 Co and making an arbitrary choice of variables, an investigation was made of the influence on properties of various carbide formers (W. Mo, Cb, V, and Ti) added singly and simultaneously, carbon variations, Cr, Ni, and Co variations and heat treatment of optimum compositions. The constitution of representative alloys was also studied.

(Continued on p. 150)

\*Abstract of "Development of a High-Temperature Alloy for Gas Turbine Rotor Blades", by G. T. Harris and H. C. Child, Symposium on High-Temperature Steels and Alloys for Gas Turbines, British Iron and Steel Institute, February 1951, p. 67.



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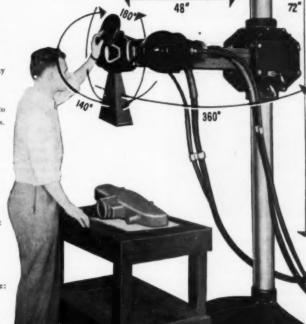


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#### High-Temperature Alloy for Rotor Blades

(Continued from p. 148)

It was found that to achieve outstanding high-temperature properties two important factors must be considered and carefully controlled: (a) The balance between the carbon and the carbide-forming elements and (b) the "complexity" effect, which requires the alloy to contain at least three carbide formers in proper proportion and balance. It is theorized that the strengthening effect of the carbideforming elements exists in such precipitation-hardened alloys as a result of empirically adjusting their compositions to slightly exceed the solubility limit at the service temperature. It is further considered that the useful aging temperature range is broadened by the precipitation of two or more phases at different temperatures. Also, the resistance to overaging can possibly be expected to increase with increasing complexity of the carbide phases formed.

An ingenious method of presenting the results as "isoproperty" contours on ternary and quaternary composition diagrams indicated that for best high-temperature properties the alloy base should be cobalt-rich (40 to 45%). About 20% chromium was necessary for scale resistance. Iron and nickel, although somewhat deleterious, were maintained around 15% for practical purposes to permit the use of ferro-alloys and facilitate machining. A combination of V-Mo-Cb additions to the base composition gave alloys with properties somewhat superior to those with W-Mo-Cb additions. The optimum strengthening composition for the base analysis was found to lie within rather small limits, around 0.3% C and a 6% total of V, Mo and Cb. While wide limits were indicated for the proportions of V, Mo, and Cb, the 2.8 V, 2.0 Mo, 1.2 Cb analysis was most attractive.

Small Ti and Al additions to alloys containing Mo-Cb improved rupture duetility without changing creep or rupture strength at 1380° F. However, such additions significantly reduced these properties at 1470° F.

The above effect of composition studies was arbitrarily made on material air cooled from 2340° F, after a 2 or 3-min. soak. Investigation of heat treatment variables indicated that water or oil quench(Continued on p. 154)



#### National's Diaphragm-Type Heart of Steel . . .



ON DIRECT-DRIVE MAXIPRESSES



ON REDUCEROLLS



**\*ON HIGH DUTY FORGING MACHINES** 

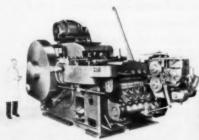
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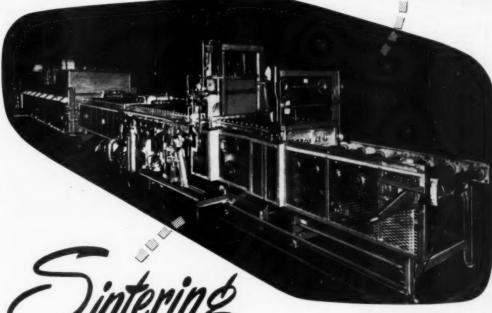
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#### High-Temperature Alloy for Rotor Blades

(Continued from p. 150)

ing from this temperature gave a marked improvement in high-temperature strength properties. Solution treatment temperatures above the solidus, which produced an intergranular eutectic-like carbide phase (this did not impair the elongation at fracture) rather than globular carbides, resulted in maximum properties. Because of possible difficulties in manufacturing resulting from such a treatment, it is recommended that temperatures at or just below the solidus for 5 to 15 min. be used. Fully aging at 1380 to 1470° F, enhanced the creep strength but had no effect on rupture strength.

The nature of the precipitated phases was studied by means of electrolytic extraction and subsequent X-ray and chemical examination. The carbide-forming power of the elements Cr, Mo, W, and Cb was found to increase in that order. Age hardening appeared to be associated with the formation of a (W,Mo,Cr,Fe)23C6 phase. Other excess constituent phases identified in 0.5 C - 20 Cr - 20 Ni - 20 Co - Mo -W-Cb alloys were Fe4(Mo,W),C and Cb<sub>4</sub>C<sub>3</sub>. In alloys containing vanadium the vanadium carbide was in solid solution in the phase (Cb,V)<sub>4</sub>C<sub>3</sub>. E. E. REYNOLDS

#### The Welding of High-Pressure Pipes\*

DEFECTS in a high-pressure pipe line of a power station initiated an investigation of the problem of manufacturing welded pipe lines capable of withstanding the high pressures they are subjected to, these ranging from 3 to 50% of the pressure head. The pipe line in this instance was made of boiler plate that had not been normalized; it was susceptible to brittle fracture. especially in the existing sheet thickness of 30 mm. (1.18 in.). For a safe service, the material should be free of the tendency for brittle fracture and its yield and tensile strengths should be as high as possible. A closely related factor is the behavior of unannealed circumfer-(Continued on p. 156)

\*Abstract of "Welding Problems With High-Pressure Pipe Lines", by H. Hauttmann, Bergund Hüttenmännischen Monatshefte, Vol. 95, December 1950, p. 314-317.

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#### The Welding of High-Pressure Pipes

(Continued from p. 154)

ential seams during service stresses. The Vereinigte Österreichische Eisen- und Stahlwerke Linz carried out pressure investigations with pipe units similar to those used in practice, each section being 39 in. long, 4.3 in, in diameter and having a wall thickness of 0.78 in. Two such sections were joined so that the longitudinal seam was translocated by 180°. In this testing arrangement, as in the pressure system, tangential forces only acted on the tube wall. At first, it was not possible to prevent the propagation of a crack, although according to the deposition weld-bending test (a flow-bend test employing a longitudinal weld bead and similar in scope to the Kinzel test) the steel was not susceptible to brittle failure. The rupture extended the entire length of the tube.

As a result of the experiments, the firm developed the so-called "Aldur" steel for welded structures which prevents the cracks on the circumferential seam from extending into the parent plate. This steel has the following composition: 0.16 C, 0.24 Si, 1.0 Mn, 0.018 P, 0.022 S, and 0.055% Al. Its yield and tensile strengths are 49,700 and 69,000 psi., respectively; elongation (1 = 5 diameters) is 33%.

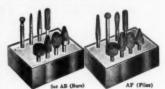
In one test the whole pipe unit, consisting of two pipe sections, was given a stress-relieving anneal. A crack developed under a pressure of 25,100 psi. at a weak spot in the circumferential seam after the occurrence of a permanent deformation of 12.6% in the circumference. The elongation to the right and left of the seam was 10 and 17.2%, respectively. The results of a pressure test on a unit having stress relieved components but with a nonannealed circumferential seam were satisfactory also. Again, only the circumferential seam cracked (the pressure being 25,900 psi.); permanent deformation at this spot was 9.9%, and the highest elongation in the plate amounted to 10.6%. As already mentioned, the crack was restricted to

The last investigations that have been carried out by this firm show that it is possible to manufacture steels with good weldability and low susceptibility to brittle fracture and having a yield strength of not less than 56,700 psi. and a tensile of 82,000 to 96,000 psi.

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METAL PROGRESS; PAGE 158

#### Mechanical Descaling Method for Wire\*

A MPORTANT innovation in wire drawing, which has taken thirty years of experimental work to evolve, is the descaling of wire rods and the drawing of satisfactory wire without the use of liquid cleaning agent and lubricant. The process consists of cracking the scale by means of multiple bending of the wire, the deformed wire then passing through a wire-brush buffing machine which is said to remove 99% of the scale before the wire enters the drawing die. The drawing lubricant is a powdered heavy metallic soap. This process and the equipment used are covered by patents held by the Société Métallurgique de Gorcy, the machinery is made under license by Liné-Jost of Albert, Somme, France. Plants operating at Luisenthal (Saar Valley) and St. Ingbert have been successfully producing 1000 tons per month since the early part of 1950.

Three important problems had to be overcome in solving the difficulties encountered in the early stages of this development. are (a) the best method of deforming the wire to properly loosen the scale, (b) a satisfactory brush to thoroughly remove the loosened scale, and (c) a dry lubricant which would permit standard reductions at ordinary drawing speeds without excessive die wear and breakage of

the wire.

After trying many variations of equipment for deforming the wire, this was simply and effectively accomplished by pulling the hot rolled rod over a pulley mounted on a vertical shaft and then passing it over a pulley mounted on a horizontal shaft. Thus the wire is bent 90° in the horizontal plane and then 90° in the vertical plane. It then passes through a nest of bufling brushes which revolve on vertical shafts perpendicular to the direction of wire travel. It is claimed that this operation removes 99% of the scale and eliminates the pickling, rinsing, sulling, lime coating and baking which are conventional practice for the "dry" wire drawing process.

A large number of brushes were investigated but the only satisfactory type was a brush having stiff. steel wire bristles. The important details regarding the brushes and (Continued on p. 160)

\*Abstract of "The Method and Results Obtained With a Machine for Descaling Wire", by Von Walter Zwierz, Stahl und Eisen, Oct. 25, 1951, p. 1133-1137.



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188	338	700	1250	1800
213	350	750	1300	1850
225	363	800	1350	1900
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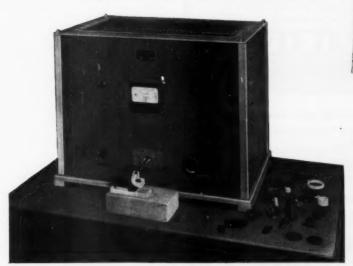
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%" steel rod 1" length in opprox. 1 second 3 seconds 15 seconds 60 seconds

Will melt 4 ounces of brass or steel in 4 minutes. Equally well suited for heating of non-ferrous metals.



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#### Mechanical Descaling Method for Wire

(Continued from p. 158) lubricants are purposely omitted in the article.

At first, the drawing dies lasted only a few hours because of the excessive wear, but this has been overcome in recent practice and dies can now be used for three or four weeks. Part of this difficulty resulted from ineffective scale removal because of poor brushes and part to uneven distribution of the lubricant, the dies wearing out very rapidly on one side. The wire must be dry and should not be processed for at least 24 hr. after hot rolling. The brushes now used are good for 150 to 200 hr. of service: the weight of scale removed approximates 22 lb. per ton of steel. Total power requirement is stated to be about 4 kw-hr. per ton over that required for pickled wire; drawing speed is 3 ft. per sec., the same as for pickled wire. Present die life is 10% less than that obtained on pickled wire. It is assumed that this refers to tungsten carbide dies. The finished product is equal in all respects to wire made from pickled rods.

Total reduction on the mechanically cleaned wire is less than for a chemically cleaned wire. It is only possible to draw from 5 mm. (0.197 in.) to 0.9 mm. (0.035 in.) before it is necessary to anneal the coil; the pickled wire may be drawn from 5 mm. (0.197 in.) to 0.6 mm. (0.0236 in.) before annealing.

All interpass or process annealing in these plants is done in bright annealing furnaces when making smaller wire sizes, so neither mechanical nor chemical cleaning is necessary. The mechanically cleaned wire is entirely satisfactory for galvanizing. This process is at present limited to wire having less than 0.30% carbon. The total cost of this process is given as:

ITEM	PER TON
Dies + 10%	0.09
Brushes	0.048
Labor	0.792
Maintenance	0.036
Transportation	0.228
Power	1.245
Lubricant	0.660
TOTAL	3.099
Scale Credit	0.600
NET COST	2,499
Total Pickling Wire Cost	9.000
SAVING	6.501

Based on the exchange rate of four Deutsch marks per dollar, this is a saving of \$1.635 per metric ton. E. C. Wright

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It pays to buy by brand—when the brandname speaks for extra performance on the job. As makers of First Quality tool steels exclusively, we say: buy Vanadium-Alloys' steels by name—and get the values added to each composition by our specialized process of manufacture . . . values that are physical, measurable, and profit-making for you!

#### Non-Shrinkable Colonial No. 6

Non-Deforming, Oil

Hardening Die Steel having excellent machining properties; low hardening temperature. Popularly used for blanking punches and dies, gauges, bushings, and miscellaneous tools.

#### Air Hard

5% Chromium Steel with minimum distortion in air hardening. Especially adapted for better wear and toughness in thread rolling dies, form and blanking dies, punches, knuris, gauges.

#### Ohio Die

Air Hardening, High

Carbon-High Chromium Steel. Free from movement in hardening, combines high wear resistance and toughness for difficult jobs. Your choice on trimming dies, shear blades, coining dies, rolls and mandrels.

#### Crocar

High Carbon-High

Chromium Die Steel with outstanding resistance to wear. Can be either air or oil hardened. Select this grade for lamination dies, wear plates, slitting cutters, and forming dies.

#### Red Star Tungsten

An unusual Oil Hardening Die Steel. Maintains keen cutting edges; excellent for punches, taps, blanking dies, spinning tools, and slitters.



Vanadium-Alloys

Columbal Stead Division

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# Conversion to liquid carburizing shortens process cycle ... eliminates need for plug quenching

Improved quality in heat treating at lower operating costs! That's the report from Wisconsin Axle Division, Timken-Detroit Axle Co., where a liquid system has replaced pack carburizing. Compact in size, this firm's "in line" liquid carburizing-martempering unit has substantially shortened the process cycle . . . produces cases of uniform depth and hardness on transmission gears. Production has increased. Manual handling of parts has been reduced. And distortion is held so low that press and plug quenching have been eliminated.

Liquid carburizing units are low in initial cost and can be readily adapted to mass production methods. The fast, even heating properties and accurate temperature control possible with these units reduce the danger of overheating and assure uniform cases—even when parts have extremely irregular sections. And distortion is held to a minimum by the buoyancy of the bath.

Perhaps your plant can profit by converting to a molten salt bath process. Get in touch with your nearest Du Pont office today. Our technical representatives will be glad to help you on heat treating problems, selection of materials, and the planning and layout of equipment. E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Dept., Wilmington 98, Delaware.

There's a Du Pont molten salt bath for every heat treating need. Sodium Cyanide, Accelerated Salt WS,\* and Carburizing Salt—for shallow, medium and deep cases—are just three of the Du Pont heat treating materials that can mean top production and maximum economy for your plant.

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DU PONT
CYANIDES and SALTS
for STEEL TREATING

# Tool Steel Topics BETHLENEM





#### 25,000 Rock Bits Forged Daily by Punches and Dies of Cr-Mo-W

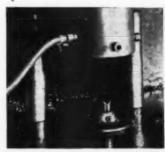
The hot-forging and trimming of steel bits for drilling rock is a pretty tough job for a tool steel. After trying several different kinds of hot-work steels, Western Rock Bit Manufacturing Co., Salt Lake City, found that our Cr-Mo-W produced more bits than more expensive and higher-alloy hot-work steels.

In the initial operation in the making of the bits, a punch of Cr-Mo-W extrudes n hot steel slug (1950 F) in a 400-ton press. In subsequent steps, the bits are trimmed to exact size by trimming dollies and water holes are pierced by punches also made of Cr-Mo-W.

This is an all-around hot-work steel containing 5 pet chromium. It's especially suited for jobs that involve shock, drastic temperature changes, and for all applica-

tions where heat-checking is a problem. Cr-Mo-W hardens in air and has good resistance to distortion during heat-treatment. It's an easy steel to machine because it can be annealed to 217 Brinell.

Like to know more about Cr-Mo-W? Write us for Booklet 265, giving details on all of our hot-work steels. Address your request to Publications Dept., Room 1041, Bethlehem, Pa.



Bits are trimmed to exact size by the trim dellie shown above. Made of Cr-Ma-W hat-work steel, its service life is about 30,000 bits.



Ultrasonic inspection of the entire length of this tool steel bar aids in detecting injurious internal defects

#### What We Mean by "Ultrasonic-Tested" Steel

Sometimes we are asked to explain the phrase "ultrasonic-tested" which appears at the bottom of our tool-steel advertisements. Well, this refers to one of the standard tests we use to safeguard the quality of tool-steel billets and large bars.

An ingenious piece of electronic equipment, known as a reflectoscope, generates millions of vibrations per second and beams these ultrasonic waves through the steel. The echo or reflection from the opposite surface of the steel appears as a wave pattern on the oscilloscope screen of the instrument so that the entire section is thoroughly probed for deviations from high quality.

Expert operators watch the screen and

interpret the "pips" or wave patterns that appear as the entire length of the bor or billet is inspected. Any injurious in ternal condition that may exist is easily recognized.

Some people are dubious of such non destructive testing methods. So were wi when we first experimented with this equipment. That's why we've sliced up hundreds of bars and billets to make sure that the ultrasonic testing was giving us a reliable picture of the internal structure of our tool steels.

It's just one of many steps in our con stant effort to avoid shipping even one bar of tool steel that's not every bit as sound as the customer expects it to be,



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Tool surfaces which are polished create less frictional heat and are less likely to gall or "pick-up." These considerations are especially important when tool surfaces have a moving contact with metals and are subject to high pressures.

On cutting tools, for example, the flow of chips across the face of the tool creates far less friction when the grinding marks are parallel to the chip movement or when grinding marks are largely

eliminated by polishing. Some twist drills and taps now have polished flutes, a feature intended to extend tool life.

It's often costly and time-consuming to polish tool wearing surfaces. But longer tool life can often make it well worthwhile.

The usual polishing procedure is to grind with a 60-grit abrasive, followed by polishing successively with 120-grit and 320-grit abrasive powder.

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**Tool Steel** 



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WITH SPERRY ULTRASONICS



Inspecting drill bits for possible fatigue cracks.



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The unexpected breakdown of production equipment has long been a costly and unpredictable expense.

The Sperry Ultrasonic Reflectoscope, the newest most advanced non-destructive testing instrument, is now being used for maintenance inspection without the necessity of time-consuming dismantling or moving of equipment to special locations.

By testing critical equipment at reasonable intervals, fatigue cracks can be detected and their subsequent growth followed, thus allowing an opportunity to schedule replacement or repair when production is least affected.

Inspections have been made successfuliy for several years on such equipment as—hoisting engine crankshafts and crankpins, sheave axles, hydraulic press cylinders, pressure and back up rolls and in most cases without time losses due to dismantling. Materials and parts produced by equipment such as this are also inspected for defects before vital machining hours are wasted.

Write for complete descriptive information on day to day commercial testing service, lease or sale of the Sperry Ultrasonic Reflectoscope.



SPERRY PRODUCTS, INC.

#### Influence of Surface Condition on Quenching Rates\*

PRIOR RESEARCH at the Max Planck Institute used silver spheres quenched in various media. Originally the temperature at the center was observed; later a technique was developed to determine the rate of temperature change directly—that is, without having first to draw the time-temperature curve. By this means various quenching media were compared.

Since the surface character has considerable bearing on the cooling rates, the present work was extended to include iron spheres with cleaned, scaled and salt-covered surfaces. Next, by quenching samples of various steels, the validity of the previous findings for silver and iron spheres was established. Temperatures were measured 0.02 in, below the surface. The experiments used a number of quenchants which can be grouped into three classes:

The first class comprises coolants which extract heat from the steel mainly by conduction and convection (exemplified by molten salts), and results in high cooling rates at high temperatures, the rates decrease as temperatures decrease.

The second class is composed of coolants which extract heat mainly by evaporation. Water and oils belong to this group. Cooling rates in these start at relatively low values and increase at lower temperatures.

The third class cools by combined action and is exemplified by water solutions of salt or caustic.

The influence of scale is shown in Fig. 1 and 2 (p. 164). The salt bath was a mixture of NaCl and KNO<sub>3</sub> melting at 285° F.; the quenching oil was a commercial product of 0.910 specific gravity, Engler viscosity of 7.5 at 20° C. and 2.2 at 50° C., and had a flash point of 330° F.

In coolants of the first class which cool by conduction (molten salt, Fig. 1), scale on the iron does not change the nature of the cooling-rate curve, but merely slows the cooling according to the thickness of the scale.

In coolants of the second class which cool by evaporation (water (Continued on p. 164)

\*Abstract of "The Influence of Surface Conditions of Metals on the Cooling Rates in Liquid Quenchants", by Walter Peter, Archiv für das Eisenhüttenwesen, Vol. 21, November-December 1950, p. 395.

#### RAMMED CHROME HEARTH

#### lasted 2 weeks



Pusher type, ail fired furnace. Temperature at entrance end 1000 F; 2400 F at discharge end.

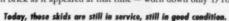
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Four months later, the furnace was down for some rearrangement of the front end. The close-up shows one of the skid rail brick as it appeared at that time — worn down only 1/16"!



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#### Influence of Surface Condition

(Continued from p. 162) or oils as shown in Fig. 2), the scale not only causes lower maximum cooling rates as compared with clean surfaces, but may change the character of the curve.

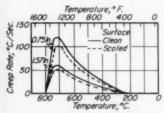


Fig. 1 — Influence of 0.04-In. Scale on Cooling Rates of Iron Spheres in Salt at 390° F.

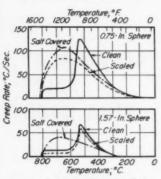


Fig. 2 — Influence of 0.04-In, Scale or a Salt Layer on Cooling Rates of Iron Spheres in Oil at 105° F.

The cooling-rate curve is of the same shape for a 1.57-in. sphere whether cleaned or scaled (the presence of scale apparently prevents formation of a vapor layer), whereas it has a different maximum for the smaller 0.75-in, sphere. The authors conclude that if the surface is covered with scale of what might be called "sufficient thickness", the cooling-rate curves are quite different from those for clean surfaces. At high temperatures (over 1100° F.) the rates of the scaled surface are then much higher than those of the clean surface, but lower at temperatures below 900° F.

In another series of experiments on oil-quenched 1.57-in. spheres, the scale was varied. Scale 0.04 in. thick gave cooling-rate curves like the lower one for scaled sphere in Fig. 2. Scale about 0.10 in. thick gave a curve of about the same

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#### Influence of Surface Condition

(Continued from p. 164)

shape as the "salt covered" curve at the bottom of Fig. 2, but it was very irregular and jagged at temperatures above 1300° F. This was apparently caused by repeated formation and subsequent collapse of vapor layers. A thickness of 0.04 in. of scale was apparently not sufficient to prevent vapor formation; "sufficiency" of a scale layer seems to depend on the thermal conductivity of the metal and the scale, and on the heat content of the sample: the larger the sphere (and therefore the ratio of heat content to the surface area) or the higher its thermal conductivity, the thicker the scale layer must be in order to be "sufficient" to prevent the formation of vapor when quenched in oil or water.

It is impossible to establish quantitatively the critical value of the ratio, heat content to surface area, because there are too many factors which influence the scale thickness and its conductivity. Moreover, these factors vary in the shop, according to the condition of the surface prior to heating, time and temperature of heating, and especially the furnace atmosphere. The conductivity of the layer is influenced by its porosity, the chemical composition of the steel. and by an air gap which may form between metal and scale. Furthermore, influence of the quenchants may be another factor.

Sometimes the charge is heated in a salt bath and it arrives in the quenching bath covered with a salt layer. Some experiments were carried out to show the influence of such a layer on the cooling rates. The results for the large and small iron spheres were the same, so reference to the 1.57-in. iron spheres will suffice. When hot specimens covered by a salt layer are quenched in molten salt or in 15% salt solution, the cooling rate versus temperature curves are slightly below those for clean specimens. These two liquids belong to the first and third class of quenchants, respectively.

The salt layer has a very pronounced influence, however, when quenching in the second class of coolants - water and oils, as shown in Fig. 3 for distilled water at 140° F. and oil at 105° F. Formation of a vapor layer is completely suppressed in oil; hence, intensive

(Continued on p. 168)



Former skeptic Russell Brooks—shown here with Cleaning Room Superintended Don Murray—no longer doubts the Panghorn LG ROTOBLAST Table's ability

"I didn't think any blast cleaning table could clean our castings efficiently," says Mr. Russell Brooks, Asst. Cleaning Room Super-intendent at the Eclipse Lawn Mower Co., Prophetstown, Ill. "I wanted proof! So we arranged for a demonstration at a nearby foundry where a Pangborn ROTOBLAST Table has been used for several years.

saving \$2100 a year on labor alone!

"Well, the demonstration was over and the castings perfectly cleaned before I realized it was started! I was sold! We ordered a Pangborn LG ROTOBLAST Table, with the idea of using it to clean about 50% of our castings. However, the performance of this table proved so superior that we now use it to clean almost our entire foundry output. We clean 3000 pieces in 4 hours . . . save \$2100 a year in labor alone, plus additional savings due to the complete elimination of breakage. And, perhaps most important, we've licked the cleaning room bottleneck we had before!"

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From a world there was the train and work to the second of the second of

#### Influence of Surface Condition

(Continued from p. 166) cooling spreads over a range including high temperatures. When quenching in distilled water, however (Fig. 3, top), a coherent vapor

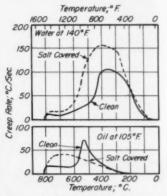


Fig. 3 — Influence of Salt Layer on Cooling Rates of 1,57-In. Iron Spheres Quenched in Distilled Water or in Oil

layer is formed which is not as stable as it is on a hot clean surface and it collapses at a temperature approximately 200° F. higher. Note that during the following boiling phase the cooling rates are approximately 50% higher than with a clean surface.

#### QUENCHING OF SMALL PIECES

The above data from iron spheres were then correlated with the quenching of small pieces of commercial steels as follows:

g	QUENCHING	
STEEL	TEMPERATURE	
C1095 (0,25 Si)	1475° F.	
C1060	1600	
C1090	1510	

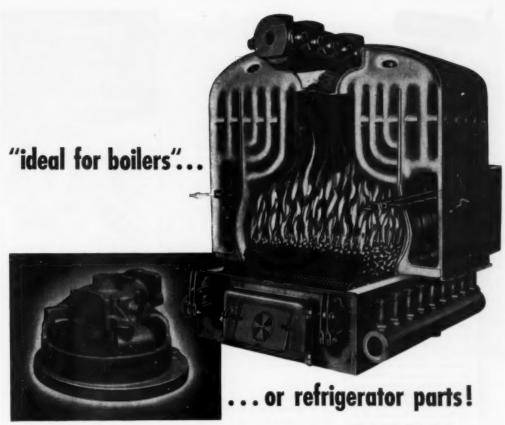
Sizes of the samples were ½ x ½ x 1½ in., ¾ in. diameter x 1½ in., and 1 in. diameter x 1½ in., respectively.

Critical points of these steels were about equal (around 1340° F.). Beginning of transformation to fine pearlite on continuous cooling was more rapid in C1095, somewhat slower in C1060, and slowest in C1080. "Nose" of the transformation curve occurred as follows:

STEEL	COOLING RATE	TEMPER-	TIME
C1095	660° F./sec.	940° F.	1.2 sec
C1060	390	930	2.4
C 1080	300	880	3.1

Martensite points were 340, 480, and 390° F., respectively.

(Continued on p. 170)



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"GRAY IRON IS IDEAL FOR BOILER CONSTRUCTION", says the manufacturer of this boiler, "because it resists to the greatest possible extent the numerous corrosive factors that attack boilers both internally and externally. Furthermore, many boilers receive indifferent or poor care. Consequently, a very durable material is necessary for their construction."

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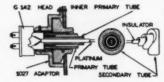
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#### Influence of Surface Condition

(Continued from p. 168)

Dimensions of the samples were so selected that high surface hardness was obtained when quenching clean specimens, so the author used hardness values to express the change of cooling conditions caused by variation of surface conditions. Inasmuch as the critical cooling rates of the steels decreased in the sequence A, B, C, dimensions of the samples were increased in the same sequence.

On quenching in a 15% salt solution the three surface conditions (clean, scaled, and covered by a salt layer) resulted in no appreciable differences in hardness. The different surfaces have, however, strong influence if quenched in distilled water or oil. Hardness of samples quenched in oil are:

> STEEL HARDNESS Bare Sample C1095 C-41 to 42 C-52 to 61 C1060 C-55 to 59 C1080 Scaled Sample C1095 C-43 to 58 C-36 to 51 C1060 C-53 to 59\* C1080 Salt Covered Sample C1095 C-43 to 60 C1060 C-49 to 58 C-44 to 52 C1080 \*C1080 with forging scale quenched to C-32 to 38.

All three steels have their maximum transformation rates in the temperature range at which the oil has its highest cooling effect. Nevertheless, hardness of steel A, with clean surface, is very low; steels B and C are at least partially hardened. This difference in hardenability can be explained by the shorter times required for pearlite to form in steel A (as compared with B and C) at temperatures above 1000° F. where the cooling effect of the oil, thanks to the vapor layer, is very small. Microstructure of steel A (fine lamellar pearlite) is also indicative. Pearlite transformation is delayed in steels B and C, and even then is not complete; this is verified from the higher hardness, and from the presence of more than 50% martensite at the surface.

Compared with a clean surface, scale may increase hardness (steel A), decrease it (steel B), or leave it unchanged (steel C). Steels A and B harden more readily and steel C less readily when quenched from a salt bath and having a layer of salt

(Continued on p. 172)



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WISCONSIN STEEL

APRIL 1952; PAGE 171



The Westinghouse "F" Frame Circuit Breaker is a 3-pole type so designed that when a fault occurs on any one of the three lines, all three contacts open and current flow stops. The Trip Bar is made common to all three lines, and each line is protected by a complete set of circuit breaker components, including a magnetic trip element and a Chace Thermostatic Bimetal trip element. One of the desirable features of this protective device is the exclusive "DE-ION" Arc Quencher for fast, sure circuit arc extinction.

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#### Influence of Surface Condition

(Continued from p. 170)

rather than of scale. The upper part of Fig. 2 may explain this for A and B. The cooling rate over the entire cooling range for the steel with salt layer lies above the curve for the scaled steel.

Hardness tests thus confirm the conclusions drawn from preliminary tests with iron spheres. In addition they show that the change of cooling rates, caused by different surface conditions, may increase or decrease the surface hardness of the steel.

Tests with iron spheres as well as quenching experiments show that when the quenchant cools by conduction and convection only, the nature of the surface does not influence the rate of heat extraction and therewith of hardening effect. If the cooling effect of a quenchant is caused mainly by evaporation, a scale or salt layer may suppress vapor formation, and this throws doubt on conclusions based on cooling rates formerly obtained on the silver spheres.

VICTOR PASCHKIS

#### "Whiskers" on Metal Surfaces\*

In tracing trouble which first was reported about five years ago in connection with failures in channel filters used in carrier telephone systems, researchers found it to be caused by the filamentary growth of extremely small and fragile "whiskers" on the leaves of electroplated variable air condensers. While only about 2 microns in diameter, some ranged up to % in. long, mostly perpendicular to the metal surface and sufficiently conductive to cause a short circuit.

The growths also appeared on cadmium-plated steel condenser leaves of military communications equipment during the early part of the war, but little investigative work has appeared on them. This led to an intensive research study by the Bell Telephone Laboratories (Continued on p. 174)

\*Abstract of "Filamentary Growths on Metal Surfaces — Whiskers", by K. G. Compton, A. Mendizza and S. M. Arnold, Bell Telephone Laboratories, Murray Hill, N. J.; first presented before National Association of Corrosion Engineers in New York and later issued as Monograph 1885 in Technical Publications of the Bell Telephone System.

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Built to take the socking heat of a continuous heat-treating furnace, this Heat-Resistant Concrete foundation was placed in 9 hours. Lumnite coment was used with pre-seaked Lelite aggregates

POURED MONDAY ... READY TUESDAY - That's the short, WHETHER YOU NEED Heat-Resistant, Refractory or Inprofitable story of this Heat-Resistant Concrete flue and foundation for a Wire Patent Furnace at John A. Roebling's Sons, Roebling, N. J. Their superintendent reports substantial savings on the job. And small wonder. It is estimated that by conventional methods this job would have taken about 2 weeks more to complete!

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sulating Concrete, you can make it quickly, easily and economically with Lumnite calcium-aluminate cement and the proper aggregates. It has a proved time- and cost-saving record for flues and furnace foundations, and for door linings, car tops, base pads, foundry floors, stack linings and many other installations.

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\*\*\* LUMNITE" is the registered t-adv mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company,

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#### "Whiskers" on Metal Surfaces

(Continued from p. 172)

in which over 1000 test specimens of different metals, solid and plated, and exposed under a variety of environmental conditions, were studied. This work has not yet been completed, but interesting preliminary data have been assembled.

The phenomenon has been observed primarily on zinc, cadmium and tin coatings. The whiskers of zinc and cadmium were found to be single crystals with a close packed hexagonal structure, oriented with an ortho-hexagonal axis parallel to the long axis of the fiber. Tin whiskers appeared to be tetragonal and to be twinned.

An environment of neither high humidity nor one contaminated by organic material is necessary, because the whiskers have developed under conditions normally considered dry and free of contaminant. While at first suspected, electroplating in itself is not the cause of the growths, since they appeared on specimens coated by other methods and on solid metal.

For a given metal, whiskers

generally developed first and to a greater extent on thinner coatings, this being noticed with regard to hot dipped coatings as well as plated coatings and wedge-shaped electrodeposits. Residues of electrolytes used to prepare specimens for plating were ruled out as causes, since the whiskers appeared on solid metal and also on metalcoated paper and mica where no cleaning was involved.

Transformation of the individual metal to a more stable form does not seem a likely explanation, particularly in the case of tin where neither heat treatment nor working greatly affected the whisker growth.

In answer to the question as to why such growths have not been encountered in the past and why there is such a limited amount of information available on them, it is suggested that the fragility of the filaments may be the explanation. Slight mechanical shock, air currents or a moderate electrical potential remove the microscopic fuzz.

Time required to grow the whiskers was established to vary widely, depending upon enrivonmental conditions and ranging from a few weeks to two years.

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Houghton Pioneering in metalworking and processing fields has resulted in a vast amount of helpful production data. Whatever your heat treating problems, ask the Houghton Man or write to E. F. Houghton & Co., Philadelphia 33, Pa.

METAL PROGRESS; PAGE 176

#### No furnace is better than its alloy parts

Leading heat treating furnace builders built much of their reputations on the performance of mechanical furnaces equipped with Q-Alloy and X-ite chains, roller rails, rotary hearths, carburizing retorts, linkage-type hearths and other mechanism. In this field, General Alloys excels in Engineering for design and function, in Metallurgy and casting quality, and, particularly, in service rendered per dollar cost. A bit higher first cost is obvious.

Users point to records of from one hundred to five hundred per cent longer life of G.A. furnace mechanism. Experience, in fact good common sense, clearly indicates that the most functional and longest life furnace parts are a sound investment, a "must" in Defense production. Top quality alloy is the best possible insurance against shut-downs (which can offset the "saving" on "cheap" alloy a hundred-fold).

alloy a hundred-fold).

Advances in pyrometry and controls, and in furnaces generally, often permit mediocre alloy parts to "get by" for the length of the furnace guarantee. Thus, it is understandable that furnaces sold on price are not equipped with G.A. products. Furnace builders make less frequent sales of alloy replacement parts when G.A. supplies the original equipment. Some consider that they will benefit in the long run by supplying their customers long-run G.A. alloy. Too, many customers don't come back for a second dose of mediocre alloy.

A large part of G.A. business is replacing "original" alloy furnace components produced by others with engineered G.A. components. Design improvements are always possible (for he who supplies "mediocre" alloys usually cuts corners in design and pattern cost).

Trays, fluxives, shoes, hangers, etc., and all "high temperature tooling" which

Trays, fixtures, shoes, hangers, etc., and all "high temperature tooling" which is not attached to, and goes in and out of, furnaces, as transport for the parts being treated, are not furnace parts. They should be individually designed for the job by the people who make them and stand behind them with "factory" engineering service. The service expectancy of such tooling doesn't start and stop on a drafting board. The integration of design with metallurgy, advanced casting techniques, controls and inspection is essential to maximum functional and economic performance.

G.A. experience and achievement in casting research and development is unique and outstanding. Its results are evident in superior products. This fact is re-ceiving increasing recognition.

High temperature tooling is becoming more complex, requiring genuine engineering. Weights, warpage and waste, and frequent repairs in service, that used to get by, are no longer acceptable. G.A. engineering prestige, advanced over 34 years, is no accident. You can rate us yourself with this simple question: "Do you consider that a better product or engineering service is elsewhere obtainable?"

H.H. H.

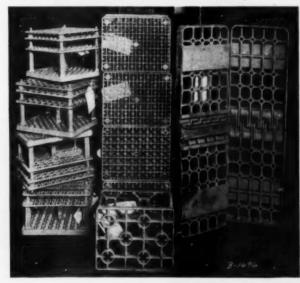
(The roller ralls shown were part of many rail designs tested at M.1.T. a desen years ago. From continuing tests of this type on all high temperature mechanism, we can authoritatively design, specify furnace parts and mechanism for new furnaces, or as replacement-from a background of unequalide experience.)

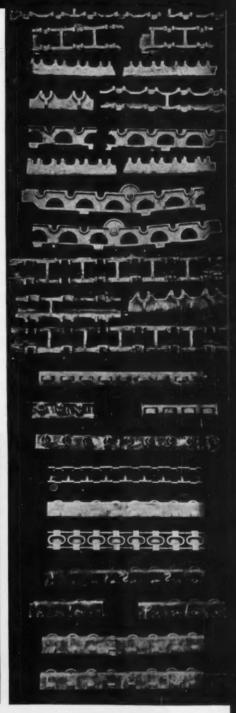
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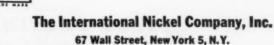
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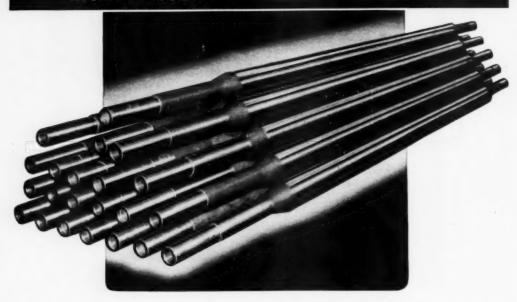
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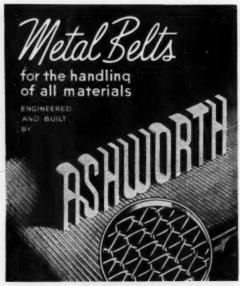
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APRIL 1952; PAGE 181



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METAL PROGRESS; PAGE 182

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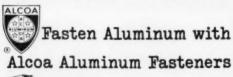
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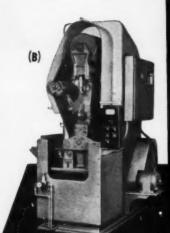
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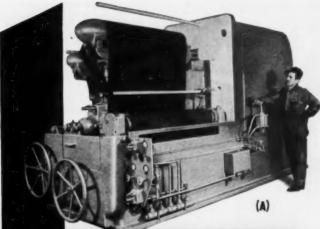
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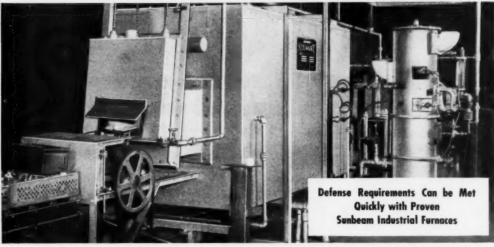


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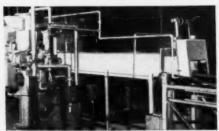


#### ELECTRIC FURNACE BRAZING OPERATIONS

At WARNER GEAR DIVISION, Borg-Warner Corporation, Muncie, Ind.



Charge and side view of Sunbeam Electric Copper Brazing furnace for copper brazing control arms. This brazed assembly, consisting of a number of machined and stamped parts, is used as a single unit, both in its heat treatment and further handling.



A 1' x 12' water jacketed cooling chamber cools the work in the protective atmosphere to a point below the oxidizing temperature. At left is a Sunbeam atmosphere generator which provides a bright finish to the work while eliminating decarburization

To provide a union that would be of sufficient strength while allowing thorough visual inspection with ease of application—and still be adaptable for subsequent heat treatment—Warner Gear copper braze various control arms used on their newly designed torque converter. Pieces vary in sizes and shapes from offset control arms weighing about  $\frac{1}{2}$  lb. and  $3\frac{1}{2}$  across to small  $1\frac{1}{2}$  x  $1\frac{1}{2}$  ratchets and cams weighing less than 3 oz.

This Sunbeam unit has a useable heating space 5' long by 1' wide with a 12" wide by  $1\frac{1}{2}$ ' charge vestibule. A water jacketed cooling chamber (1' x 12') cools the work in a protective atmosphere.

With slight modifications, this Sunbeam furnace can be used for both annealing and copper brazing high alloy and stainless steels. Availability of this equipment as a continuous production unit varies from 50 lbs./hr. up to 1000 lbs./hr. Flexibility of this furnace enables designers to utilize the simplicity in design and manufacture of brazed assemblies.

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FORGINGS: Rotary Hearth and Pusher-type Forging Furnaces. Sunbeam

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A letter, wire or 'phone coll will promptly bring you information and details on SUNEEAM industrial furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a SUNBEAM engineer will be glod to coll and discuss your heat treating problems with you.

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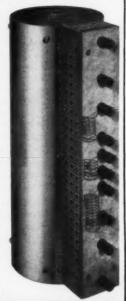
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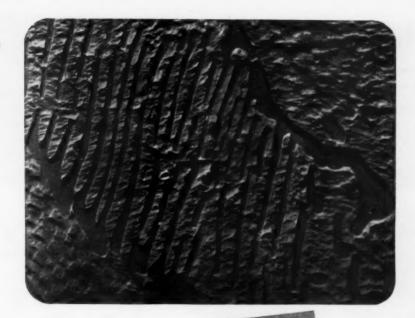
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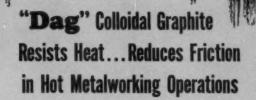
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